KOOTENAI RIVER WHITE STURGEON INVESTIGATION

ANNUAL PROGRESS REPORT

KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

Period Covered: January 1, 1997 to December 31, 1997

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ABSTRACT

The Kootenai River at Bonners Ferry rose above flood stage during 1997. Exceptionally heavy precipitation and 130% + snow pack in the drainage raised flows in Bonners Ferry to over 1,526 m^3/s (54,000 cfs) during April and May. The peak flow for the season reached 1,547 m^3/s (54,600 cfs) on May 14. Nearly all of the flow in April and May was local inflow. Consequently, water management at Libby Dam was primarily for flood control for the Kootenai River Valley; discharge from Libby Dam was held to only 162-354 m^3/s (5,700-12,500 cfs) for the entire month of April. Despite these efforts, flood conditions still prevailed in the lower portion of the drainage.

Sixty-one individual adult white sturgeon *Acipenser transmontanus* were captured with 2,500 hours of angling and setlining effort between March 1 and March 31, 1997. Sonic and radio transmitters were attached to three mature females and four males. We monitored about 15 mature adults in the spawning reach during spring of 1997.

Two flow/temperature tests were implemented during white sturgeon spawning. These tests were called for by the US Fish and Wildlife Service with the supposition warm water would entice white sturgeon to the cobble substrate at Bonners Ferry and spawn. The first flow/temperature test for white sturgeon spawning was initiated on June 5 and flows reached 1,320 m^3/s (46,600 cfs) on June 6. Temperature rose from about 9.1°C (48.3°F) on June 4 to 10.1°C (50.2°F) on June 6. Flows at Bonners Ferry were reduced slightly to 1,220 m^3/s (43,000 cfs) by June 10 and then increased with augmented flows from Libby Dam to produce 1,270 m^3/s (44,700 cfs) by June 12 at Bonners Ferry. Temperature during the second test increased from 10.1°C (50.2°F) to 11.4°C (52.5°F) on June 12. Flows were gradually ramped down after the second test and were as low as 595 m^3/s (21,000 cfs) by mid-July. White sturgeon spawning location, timing, frequency, and habitat was evaluated by sampling for eggs with artificial substrate mats. Mats were deployed on May 15, checked daily, and retrieved on July 10, 1997. A total of 75 eggs (one was an egg shell) and one larval sturgeon were collected with a total of 3,756 mat days.

White sturgeon eggs were collected between June 5 and June 24. Ten possible spawning events took place with the three largest events occurring on: June 10 (28 eggs), June 11 (8 eggs) and June 20 (8 eggs). Flows on June 10 and 11 were increasing and the *flow* on June 20 was dropping. Seven other possible spawning dates yielded from one to three eggs each. Fifty-seven (77%) of the 75 white sturgeon eggs and the one larvae collected in 1997 were viable. Stages of egg development ranged from stage 12 to 28 (1 h to 14 d old), with 76% of the eggs at stage 21 or earlier. Based on ages of viable eggs and dates of egg collection we estimated white sturgeon spawned during a minimum of 10 days in 1997. Although a large percentage of eggs were older than 72 hours, most eggs were captured soon after spawning events. Sixty-nine percent of the eggs were less than two days old, 7% were 48 to 72 hours old, but 24% were greater than 72 hours old of which all were older than nine days. The four oldest eggs were estimated at 293 hours old or about 12 days. Average stage for sturgeon eggs collected in 1997 and 1996 was significantly older (P=0.0001) than those collected in 1994 and 1995. Average stages were 19 (1997), 19 (1996), 16 (1995) and 15 (1994). Location of eggs collected from 1994 through 1997 has been sequentially further upstream, simultaneously Kootenay Lake has been higher each year. We found no evidence to suggest that the temperature tests were any benefit to sturgeon spawning. Juvenile sampling produced a total catch of 48 individual sturgeon of which 44 were hatchery and four were wild. The wild juveniles were recruits from flow test years.

Analysis of the stomach contents of 23 juvenile white sturgeon indicated Chironomids are the major food source. Recommendations for the 1998 spawning season include a test to begin when river temperature approaches 9°C (48°F) and discharge should be in increments of 57 m^3/s (2,000 cfs) per day to a minimum of 1,130 m^3/s (40,000 cfs) at Bonners Ferry. We also recommend no load following. Recent disclosures from the United States Army Corps of Engineers (USACE) indicate discharges below 1,425 m^3/s (50,000 cfs) cause no serious jeopardy to lands adjacent to the river. Thus, flows for sturgeon spawning should not adversely impact agricultural interests.

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OBJECTIVE

1. Determine environmental requirements for adequate spawning and recruitment of white sturgeon *Acipenser transmontanus* by 1998.

STUDY SITE

The Kootenai River originates in Kootenay National Park, British Columbia (BC). The river flows south into Montana and turns northwest at Jennings, the site of Libby Dam, at river kilometer (rkm) 352.4 (Figure 1). Kootenai Falls, 40 km (24.8 mi) below Libby Dam, is thought to be an impassable barrier to sturgeon. As the river flows through the northeast corner of Idaho, there is a gradient transition at Bonners Ferry. Upriver from Bonners Ferry the channel has an average gradient of 0.6 m/km (3.15 ft/mi) and the velocities are often higher than 0.8 m/s (2.6 ft/s). Downriver from Bonners Ferry the river slows with velocities usually less than 0.4 m/s (1.3 ft/s), average gradient is 0.02 m/km (0.1 ft/mi), the channel deepens, and the river meanders through the Kootenai Valley. The river returns to British Columbia at rkm 170 and enters the South Arm of Kootenay Lake at rkm 120. The river leaves the lake though the west arm to its confluence with the Columbia River at Castlegar, British Columbia. A natural barrier at Bonnington Falls (now a series of four dams), has isolated the Kootenai River white sturgeon from other populations in the Columbia River basin for approximately 10,000 years (Northcote 1973). The basin drains an area of 49,987 km^2 (19,300 mi^2) (Bonde and Bush 1975). Impounding the Kootenai River with Libby Dam reversed the natural hydrograph (Figure 2). However, since 1991 mitigative flows have further changed the hydrograph (Figure 2).

METHODS

Discharge and Water Temperature

Kootenai River discharge and water temperature data at Bonners Ferry and discharge from Libby Dam were obtained from USACE. Two experimental flow/temperature tests were designed by the U. S. Fish and Wildlife Service (USFWS), with assistance from USACE, to enhance white sturgeon migration and spawning. In early June, two peaks were created during the flow tests, with the first test starting on June 5 and the second on June 12, each test was about four days duration. Each peak flow was to be about 1,275 m^3/s (45,000 cfs conversions to cfs are rounded to hundreds) at temperatures of 10 and 12 °C (50 and 53.6 °F). Temperature was to be controlled by manipulating the location of water withdrawn from Libby Dam.

Adult White Sturgeon Sampling

Adult white sturgeon were captured with rod and reel or set lines from March 1, 1997 to March 31, 1997. Sampling was carried out in accordance to methods cited in Paragamian et al. (1996). Some adult white sturgeon were tagged with radio and sonic tags and monitored to determine movements during the spawning season (Paragamian et al. 1996).

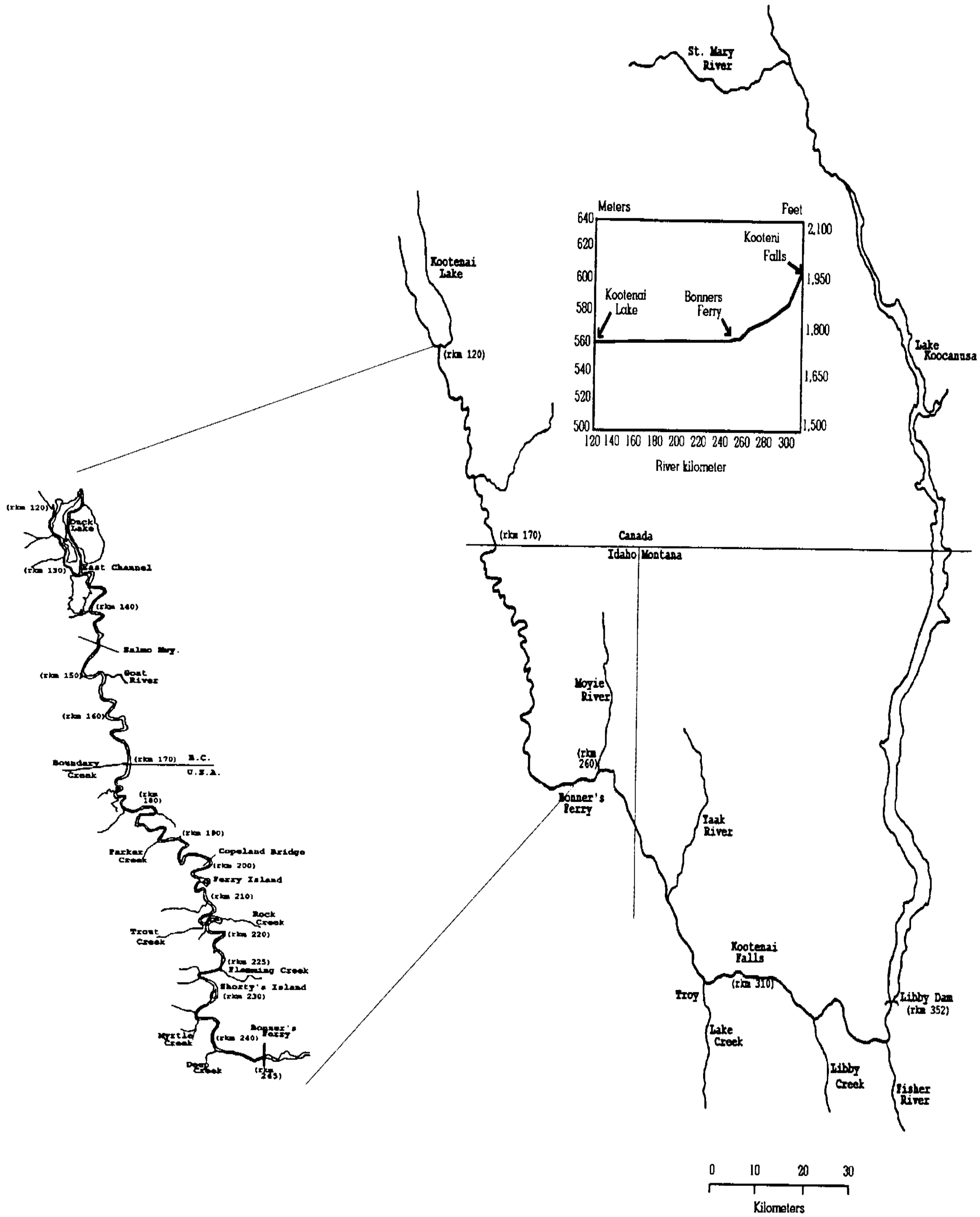


Figure 1. Map of the Kootenai River with a schematic of river gradient and notable points of reference from Bonners Ferry to Kootenay Lake. Complete study area was from southern Kootenay Lake upriver to Kootenai Falls.

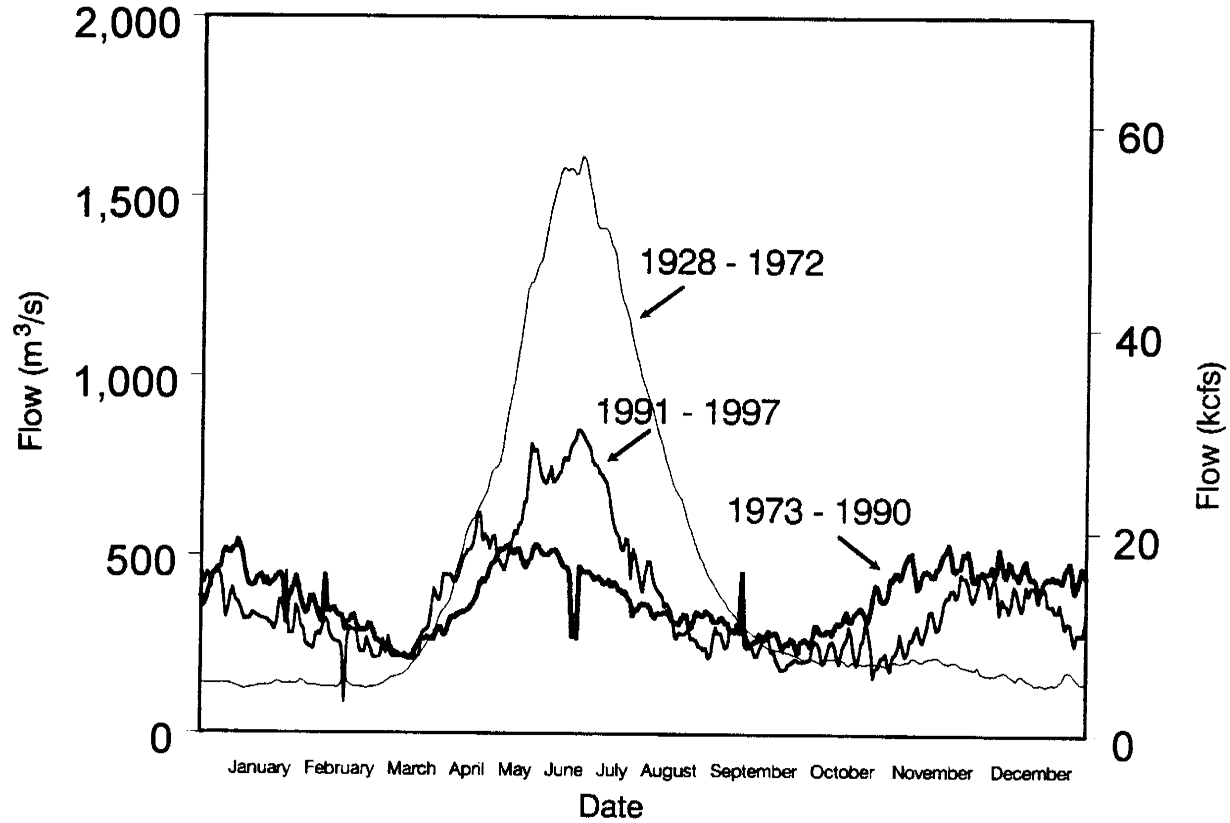


Figure 2. Mean monthly flow patterns in the Kootenai River at Bonners Ferry, ID from 1928–1972 (pre-Libby Dam), 1973–1990 (post-Libby Dam), and 1991–1997 (post-Libby Dam with augmented flows.

Adult White Sturgeon Telemetry

Movement and migration of adult white sturgeon fitted with sonic and radio transmitters were monitored monthly from the Kootenai River at Bonners Ferry to the river's delta at Kootenay Lake, and from the delta to the north end of the lake. The main objective was to locate late vitellogenic females and males migrating upstream to staging and spawning reaches. As sturgeon activity increased, monitoring effort increased. Each transmitter location was recorded to the nearest 0.1 rkm (0.061 mi). Surface water temperature was measured daily with a hand-held thermometer.

Effort required to monitor sturgeon movement and activity varied with season. Less effort was required during winter months when most fish moved less frequently than in spring and fall. Increased activity of tagged fish during the pre-spawning and spawning seasons required more frequent monitoring. Reaches above Copeland (Figure 1) were monitored more intensively than downriver or lake sections, especially during the pre-spawning and spawning periods when mature sturgeon moved upstream.

Two fixed-location receivers were stationed upriver from the spawning reach (rkm 237.4 and 245.2) from May 2 to July 28, 1997. Both receivers were moved to new locations in 1997. A new position was selected to detect fish movements above the Myrtle Creek spawning location (rkm 237.0). A new upriver Bonners Ferry location (rkm 245.2) was also selected in an effort to detect fish movements above Ambush Rock (rkm 244.5) and eliminate some of the background noise problems experienced at the upriver site on the north side of the Kootenai River in 1996. Radio frequencies of suspected spawners were programmed into the receivers, which were checked every other day.

Artificial Substrate Mat Sampling

Adult white sturgeon locations were assigned to high, medium, and low densities for observations of sonic and radio tagged fish. These were based on observations from previous years; high-sturgeon were frequently located, medium-sturgeon were occasionally located, and low-sturgeon were seldom located. Egg mat densities in the spawning area were then based on general densities of monitored sturgeon in previous years. We set an average of 1.9 mats/0.1 km in the high-density sections (25 mats), an average of 1.05 mats/0.1 km in the medium-density sections (21 mats), and an average of about one mat/6.25 km in the low-density sections (24 mats). Some of the high and medium 0.1 km sites were sampled with two mats. The sites that were sampled with two mats were chosen randomly from all high or medium density sites, all mats were set in or near the thalweg. A one km reach from rkm 230-231 was not sampled because it was a brood stock collection reach for the Kootenai Tribe of Idaho (KTOI). The Kolmogorov-Smirnov non-parametric test was used to compare the distribution of eggs between years while the Kruskal-Wallace test one-way nonparametric test was used to detect any differences in the water velocities between locations of eggs.

The area near the highway 95 bridge was a low-density site and we felt it was necessary to increase the effort in that area, thus ten additional mats were deployed above rkm 245. The effort for these mats was not used to calculate total catch per unit effort (CPUE). Two additional test mats equipped with posterior attached drift nets were deployed at rkm 236 and rkm 245.8 to capture drifting eggs and larvae. Each drift net was 30.48 cm x 63.5 cm x 60.96 cm (12 in x 25 in x 24 in), 3 mm (0.1 in) mesh polyester netting with an 8.1 cm (3.19 in) diameter collecting bucket attached at the cod end. Eggs were collected, preserved in a formaldehyde solution and staged according to Paragamian et al. (1996).

Juvenile White Sturgeon Sampling

Weighted multifiliment gill nets with 2.5 cm to five cm (one-two inch) mesh and shrimp trawls were used to sample juvenile and young-of-the-year (YOY) sturgeon (Paragamian et al. 1996; Fredericks and Fleck 1996). Gill nets were fished at various locations between rkm 174 and rkm 236. They were set during the day and checked every hour. Juvenile sturgeon were processed and shrimp trawls were carried out by methods cited in Paragamian et al. (1996).

Juvenile White Sturgeon Telemetry

Hatchery released juvenile white sturgeon with active sonic tags (Marcuson et al. 1995; Paragamian et al. 1996) were tracked to document movement and habitat use. We assumed habitat choice of hatchery juveniles could be an indicator of habitat selection in wild juvenile sturgeon.

Juvenile White Sturgeon Food Habits

We studied the food habits of hatchery white sturgeon in the Kootenai River by examining the stomach contents of fish recaptured during juvenile sampling. Only age-2 hatchery white sturgeon (1995 year-class) were used for food habit analysis. The sacrifice of up to 25 hatchery white sturgeon was authorized in our Section 10 Permit. Hatchery fish captured during sampling that were evaluated for food habits were weighed and measured (TL and FL). An incision was made in the abdominal wall to insure preservation of the stomach and its contents, then the fish was placed in a quart jar containing formalin. The date and location of the collection was noted. The stomach contents were identified to genus (if possible), enumerated, and dry weighed in the lab.

Age and Growth of White Sturgeon

Ages of adult and juvenile white sturgeon were determined by pectoral fin ray analysis (Marcuson et al. 1995; Paragamian et al. 1996). Age information was used to determine year class structure.

Larval Sturgeon Sampling

We used sub-surface meter net tows, dual half meter net tows (one sub-surface and one 3-4 m (9-15 ft) below the surface), passive D-ring sets, and shrimp net trawling to search for larval white sturgeon in the Kootenai River and Kootenay Lake. A mid-water trawl was also used in the South Arm of Kootenay Lake concurrent to our studies with British Columbia Ministry of Environment (BCMOE) (Robert Lindsay BCMOE, personal communication) and a beam trawl by researchers from Montana Department of Fish Wildlife and Parks (MDFWP).

We used two techniques for meter net sampling. In the Kootenai River, sub-surface tows were made during daylight hours. Tows were made between rkm 121 to rkm 239. Most meter net tows in the river were between rkm 191 and rkm 237 (in the vicinity of sturgeon egg collections or downstream). In Kootenay Lake, we sampled bi-weekly with paired half-meter net tows at four transect sites in the South Arm (rkm 118-119) from March 20 through August 7. Site one started about 400 meters offshore from Kuskanuk at a depth of about 75 m, each of the remaining sites continued from east to west. The four sample sites covered about 80% of the width of Kootenay Lake in the South Arm. Site three was due north of the Kootenay River delta mouth. The meter net was towed for a period of 16 to 20 minutes (see Fredericks and Fleck 1996 for a more detailed description).

Shrimp trawl sampling was restricted to the Kootenai River (rkm 175 through 231.6). Sampling was performed during daylight hours from August 12 through September 4, 1997. The shrimp trawl provided the opportunity to sample the bottom of the river with gear that would be selective for "fingerling" sized sturgeon. For more specific sampling details see Fredericks and Fleck (1996).

Contaminants

Fifteen-gram egg samples were biopsied from stage 3 and 4 females (Appendix 1) captured during adult sampling. Samples were frozen in plastic vials that had been double rinsed in pesticide grade acetone. Eggs were frozen until they could be analyzed for pesticides, PCB's and metals.

Mitochondrial DNA analysis

We used mitochondrial DNA (mtDNA) analysis to explore the possibility there are several stocks of white sturgeon in the lower Kootenai Basin and that they may be spatially segregated. For this study mtDNA was extracted from fin ray tissue of white sturgeon captured at three different locations; the Kootenai River, the Kootenay delta of Kootenay Lake, and Duncan Lake (Figure 1). Collection of tissue samples from white sturgeon fin rays was a cooperative effort; we collected samples from fish captured in the Kootenai River while samples from Kootenay and Duncan Lakes were collected by the fisheries staff of BCMOE. All mtDNA analysis was completed at the University of Idaho Aquaculture Research Institute using standard techniques (Sambrook et al. 1989 and Dowling et al. 1990) and under the direction of Dr. Matt Powell.

Acoustic Doppler Current Profiles

Acoustic Doppler Current Profiles (ADCP) (Morlick 1996) were collected from three 0.5 km reaches of the Kootenai River near Bonners Ferry. The objective was to determine any unique qualities in river currents that are preferred by Kootenai River white sturgeon for spawning. We believed this objective could be achieved by characterizing river currents in three different areas; in a river reach adult sturgeon pass through and therefore find conditions unacceptable for spawning (rkm 226.5-227), in a segment of the spawning reach (rkm 236-236.5), and in a reach thought to be suitable for spawning and from which eggs were collected in 1991 and 1993 (rkm 245-245.5). Fifty-one transects were run with the ADCP instrument at each reach while vertical current profiles were at one m intervals. The ADCP instrument measured current profiles in three dimensions.

RESULTS

Discharge and Temperature

The Kootenai River at Bonners Ferry rose above flood stage (1,417 m^3/s or 50,000 cfs) during 1997. Exceptionally heavy precipitation and 130% + snow pack in the drainage raised flows in Bonners Ferry to over 1,526 m^3/s (54,000 cfs) during April and May (Figure 3). The peak flow for the season reached 1,547 m^3/s (54,600 cfs) on May 14. Most of the flow in April and May was local inflow. Consequently, water management at Libby Dam was primarily for flood control at Bonners Ferry and the Kootenai River valley. Discharge from Libby Dam was held to only 162-354 m^3/s (5,700 -12,500 cfs) for the entire month of April. Despite these efforts, flood conditions still prevailed in the lower portion of the drainage because of the volume of local inflow.

The first test flow was initiated on June 5 and flows reached 1,320 m^3/s (46,600 cfs) on June 6. Temperature rose from about 9.1°C (48.3°F) on June 4 to 10.1°C (50.2°F) on June 6 (Figure 3). The first test ended when flows at Bonners Ferry were reduced slightly to 1,220 m^3/s (43,000 cfs) by June 10 and then increased with augmented flows from Libby Dam to produce 1,270 m^3/s (44,700 cfs) by June 12 at Bonners Ferry, which was the beginning of the second test. Temperature during the second flow test increased from 10.1°C (50.2°F) to 11.4°C (52.5°F) on June 12 and following ramp down on June 13 it was 12.3°C (54.1°F) for three days. Flows were gradually ramped down after the second test and were as low as 357 m^3/s (12,600 cfs) by the end of July.

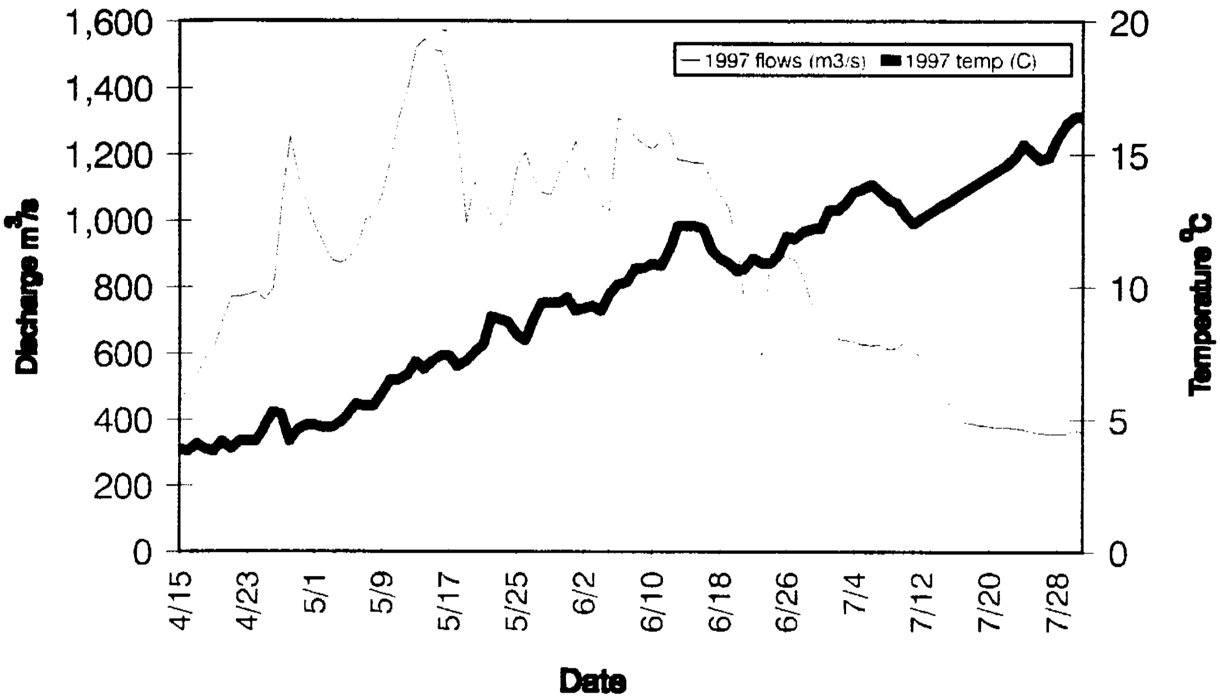


Figure 3. Temperature (°C) and flow (m^3/s) in the Kootenai River at Bonners Ferry, Idaho.

Adult White Sturgeon Sampling

Sixty-one individual adult white sturgeon were captured with 2,500 hours of angling and setlining effort between March 1 and March 31, 1997 (Table 1). One additional adult white sturgeon was captured in a gillnet while sampling for juveniles, for a total of 62 fish. Twelve white sturgeon were caught a second time in 1997 (11 by setline and one in a gill net) for a grand total of 74. Thirty-one (42%) of the 74 sturgeon captured were recaptures from previous years.

Catch per unit effort (CPUE) for adult white sturgeon caught by angling and set line gear was 0.07 and 0.02 fish/h, respectively. Catch per unit effort for adults caught in juvenile gillnet was 0.004 fish/h (Table 1).

A total of 72 biopsies was performed on adult sturgeon to determine sexual maturity stage of ovaries and testes (20 females, 38 males, 14 unknown) (Appendix 1). Sonic and radio tags were attached to three female and four male fish during this effort.

Table 1. Sampling effort and number of adult and juvenile white sturgeon caught by the Idaho Department of Fish and Game in the Kootenai River, Idaho, March 1, 1997 to April 30, 1997.

Gear type	Hours of effort	Number of juvenile sturgeon caught	Number of adult sturgeon caught (No. individuals)	Juvenile CPUE (fish/h)	Adult CPUE (fish/h)
Hoopnet	461.6	0	0 (0)	--	--
Gillnet (2.4-7.6 cm mesh)	534.5	47[a]	2 (1)	.10	.004
Rod & Reel [a]	104.7	0	7 (4)	--	.07
Setline[a]	2,395.7	0	65 (57)	--	.02
Shrimp trawl	39.58	1	--	.07	--
TOTAL	3493.5 639.2[c]	48	74 (62)		

[a]Of this total three hatchery fish were caught a second time in 1997.
[b]Gear targeting adult white sturgeon only.
[c]Effort for gear that targeted adults only.

Adult White Sturgeon Telemetry

Fifty-one white sturgeon with active transmitters were monitored for a total of 637 h of effort from September 1, 1996 to August 31, 1997 (Figure 4, Table 2, and Appendix 2). From April 1 through August 31, 1997, 14 of the 51 tagged fish (8 males and 6 females) were monitored specifically for pre-spawn and spawning activities. Locations, river discharges, and temperatures during the migration and spawning period are displayed for these 14 suspected spawners (Appendix 2). Two hundred and seventeen trips were made throughout the study area to monitor radio and sonic tagged sturgeon during the pre-spawn and spawning period in 1997. Twenty-one trips targeted the section from the Kootenai River delta of Kootenay Lake to Creston boat ramp, 22 trips from Creston boat ramp to Porthill, 54 trips from Porthill to Copeland, 60 trips from Copeland to Flemming Creek and 60 trips from Flemming Creek to the confluence of the Moyie River (Figure 5).

Migration of Monitored Sturgeon in 1997

Twenty-five adult males and 26 females carried transmitters in 1997 (Table 2). Five males and 13 females remained in Kootenay Lake during the pre-spawn and spawning period. Of the above lake dwelling fish, one was tagged in 1993, three in 1994, six in 1995 and eight in 1996. Eight males and four females made brief movements out of the lake and into the lower river (rkm >122<203). An additional three males and three females went upriver as far as Flemming Creek (rkm 225) during the spawning period. We tracked the remaining eight males and six females to locations upstream of Flemming Creek. These 14 sturgeon migrated to spawning locations in the upper Kootenai River during times when eggs were collected (Table 3). The furthest upriver location was at rkm 245.2 near Ambush Rock (1 male and 1 female).

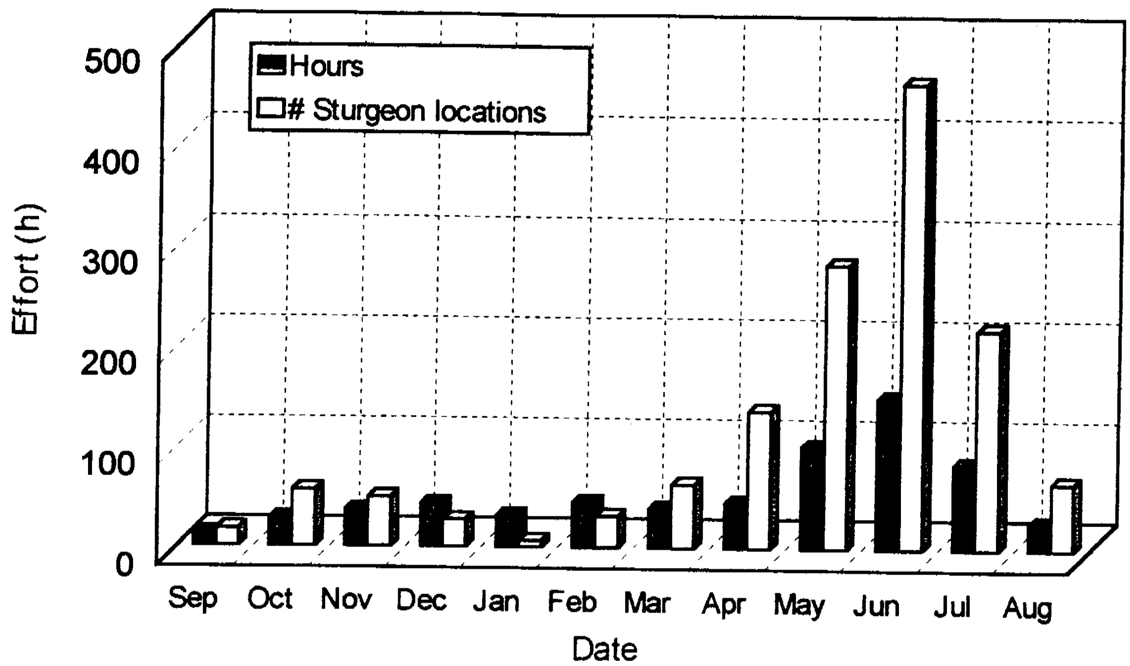


Figure 4. Telemetry effort (hours) and number of times white sturgeon were located monthly from September 1, 1997 to August 31, 1997. Kootenai River, Idaho.

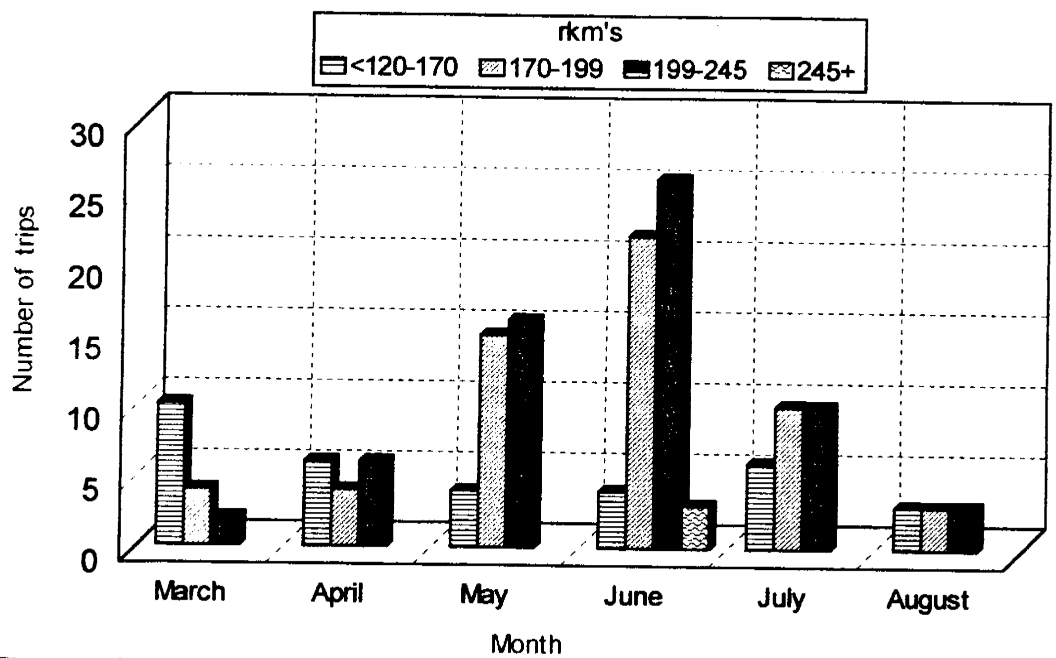


Figure 5. Telemetry effort (number of boat trips) by river kilometers section in the Kootenai River, Idaho and Kootenay Lake, BC, for March 1, 1997 to August 31, 1997.

Table 2. Upriver locations of monitored white sturgeon that moved out of Kootenay Lake, BC, from April 1,1997 to August 31,1997.

Fish #		Tagging location (rkm)	Date tagged	Highest rkm (Date)			Last date located above rkm 225
Male	Female			>122<203	>203<225	>225	
--	163	215	4/26/94	--	214.5(6/12)[b]	--	--
--	250[a]	215.1	9/11/96	--	--	245.2(7/3)	7/31
--	348	203	4/1/94	--	--	229.6(8/12)[e]	8/18
349[a]	--	240.5	6/1/91	--	--	239(6/13)	6/20
--	403	230.9	5/20/92	138.5(7/29)	--	--	--
407[a]	--	215.6	3/6/96	--	--	231(6/12)	8/18
--	409[a]	215.5	3/19/97	--	--	237.4(6/3)	6/8
--	436	207.8	4/27/93	c	--	--	--
--	530	118	2/12/94	140(8/19)	--	--	--
--	560	204.5	3/18/94	--	205.5(6/2)[b]	--	--
565[a]	--	193	3/19/94	--	--	240.5(5/30)	6/30
568	--	215.5	3/19/94	c	--	--	--
--	569	215.5	3/19/94	c	--	--	--
--	576	215.0	3/31/94	--	--	228.2	shed tag
581	--	215.0	4/6/94	c	--	--	--
585	--	203	4/18/94	177.2[b]	--	--	--
--	617[a]	215.6	3/17/97	--	--	239.5(5/27)	6/3
620	--	205	3/20/95	136.5[b]	--	--	--
621	--	215	3/20/95	--	209.5(7/16)	--	--
624	--	215.4	3/24/95	c	--	--	--
--	625	215.4	3/24/95	c	--	--	--
--	628	215	3/29/95	c	--	--	--
--	629	215	3/29/95	c	--	--	--
--	636	205	4/4/95	c	--	--	--
637	--	205.3	4/4/95	133.5	--	--	shed tag
--	649	205	4/12/95	176.5(5/22)[b]	--	--	--
--	714	205	3/5/96	c	--	--	--
--	715	215.6	3/5/96	c	--	--	--
--	718	215.5	3/5/96	c	--	--	--
720	--	215.6	3/6/96	156(6/11)	--	--	--
722	--	215.5	3/7/96	140.5(8/5)	--	--	--
--	723	215.7	3//96	133(8/28)	--	--	--
--	730	215	3/12/96	c	--	--	--
732	--	215	3/14/96	c	--	--	--
779[a]	--	215.7	3/4/97	--	--	245.2(6/24)	7/11
781[a]	--	215.5	3/10/97	--	--	240(5/26)	6/26
785[a]	--	215.7	3/13/97	--	--	238.5(6/2)	7/4

Table 2. Upriver locations of monitored white sturgeon that moved out of Kootenay Lake, BC, from April 1,1997 to August 31,1997 (continued).

Fish #		Tagging location (rkm)	Date tagged	Highest rkm (Date)			Last date located above rkm 225
Male	Female			>122<203	>203<225	>225	
787[a]	--	215.6	3/18/97	--	--	240.5(5/30)	6/23
--	788[a]	215.6	3/18/97	--	--	240(6/6)	6/14
2057	--	215	3/29/95	c	--	--	--
--	2176	17	8/17/94	c	--	--	--
2192[d]	--	83	8/10/94	--	208.9(7/24)	--	--
2194[d]	--	83	8/6/94	--	--	--	--
2276[d]	--	121	9/28/95	150.1[b]	--	--	--
--	2308	17	8/1/96	c	--	--	--
2320	--	17	8/1/96	147(7/25)	--	--	--
2334	--	77	9/6/96	--	215.8(8/18)	--	--
--	2335[a]	77	9/17/96	--	--	236(6/29)	7/6
2336	--	17	10/8/96	c	--	--	--
2337	--	17	10/29/96	194.2(8/18)	--	--	--
--	2338	17	10/9/96	c	--	--	--
n=18	n=21	Non-spawners (n=39)					
n=7	n=5	Spawners (n=12)					
n=25	n=26	Combined (n=51)					

a Suspected spawners in 1997.
b These fish overwintered in this river section - all others were either tagged during 1997 or overwintered in Kootenay Lake.
c These fish did not make any upriver movement out of Kootenay Lake in 1997
d These fish were not sexed prior to tagging
e This fish stayed below rkm 225 during the spawning season

Table 3. Fish tracked to sections of the Kootenai River, Idaho, where white sturgeon eggs were spawned (back-calculated to spawning date), within 24 hours preceding spawning date.

Location	Egg spawn date	Fish #	
		Males	Females
Upper Shorty's Island (rkm 231.6-233.4)	6/11	787	
Myrtle Creek (rkm 233.5-234.7)	6/11	787	
	6/12	407	
	6/13		
	6/14		
	6/15		
Wildlife Refuge (rkm 234.8-237.5)	6/9	349	250
	6/10	787	788
	6/11		2335
	6/12		
	6/20		
	6/21		
Deep Creek (rkm 237.6-240.5)	6/10	349	788
	6/13	565	
		779	
		781	

[a] This assumes that eggs were spawned in the same river reach where they were collected.

Fixed-Receiver Results

The fixed-receivers gave us results that are more reliable in 1997 than the previous year, even with high flows and turbidity in the river. However, there was still some background noise that occasionally interfered with the receivers ability to differentiate noise from actual radio frequencies 100% of the time. Consequently, only verified locations were recorded in Appendix 2. The three-element yagi antennas were able to detect the movements of six fish past the fixed-receiver stations. This included three females (numbers 617, 409, 250) and three males (numbers 787, 781, 779). The upriver movements were supported by previous and later locations of the same radio frequencies from the boats. Fixed-receiver locations at rkm 245.2 represent the highest known upriver locations for two fish (female 250 and male 779) in 1997.

Artificial Substrate Mat Sampling

We sampled for a total of 4,256 mat days in the Kootenai River during the 1997 spawning season. Average set time for all mats was 27 hours, and 67 hours for mats containing eggs. Although mats were checked daily, high water conditions, and debris during sampling in 1997 made it difficult to find all of the mats each day. Thus, some mats were out for several days before they could be relocated. The total sampling time for egg mats was 102,133 hours to collect 75 eggs (one was an egg shell) and one larval sturgeon (Table 4). We expended 69,879 h of mat sampling effort between rkm 228 to 240.5 and 32,254 hours of effort above rkm 240.5 (Appendix 3). Egg collection catch effort was 1,429 h/egg.

Table 4. Location (rkm), depth (m), effort and white sturgeon egg catch by artificial substrate mats, Kootenai River, Idaho, 1997.

Geographical description	River location (rkm)	Average Depth (m)	Total Sample hours[a,b]	Number white sturgeon eggs
Lower Shorty's Island	228.0-229.5	36.5	9,756.2	0
Middle Shorty's Island	229.6-231.5	36.4	9,405.7	0
Upper Shorty's Island	231.6-233.4	34.1	9,313	1
Myrtle Creek	233.5-234.7	34.5	13,082.2	11
Refuge	234.8-237.5	35.2	15,990.4	33[c]
Deep Creek	237.6-240.5	33	12,331.2	30
Hatchery	240.6-243.9	30.8	8,545	0
Ambush Rock	244.0-244.6	33	50.5	0
US 95	244.7-246.6	16.4	19,313.7	0
Upper Pump Station	246.7-247.7	15.9	4,345.3	0
All sections	**228.0-247.7**	**29.9**	**102,133.2**	**75[c]**

[a] Sampling effort for mats that were stuck and not retrieved after 10 days were not included in the total sampling effort.
[b] One mat sample is equal to the time a mat is in the river before it is pulled and checked.
[c] One of these eggs was a hatched out white sturgeon egg shell.

Depth of artificial substrate mat placement ranged from 1.2 to 19.5 m (4 to 64 ft) for all mats (Appendix 4). Depth ranged from 6.7 to 18 m (22 to 59 ft) and averaged 13.3 m (43.6 ft) for mats that collected eggs. Temperature at egg collection sites ranged from 9.7 to12.3°C (49.4 to 54.1°F). Surface velocities at all 14 egg collection sites ranged from 0.36 to 1.03 m/s (1.18 to 3.38 ft/s) and averaged 0.68 m/s (2.23 f/s). Velocities near the river substrate at all 14 of the egg collection sites ranged from 0.26 to 0.99 m/s (.85 to 3.25 ft/s) and averaged 0.66 m/s (2.17 ft/s).

The 75 sturgeon eggs (including one egg shell) and one larval white sturgeon were collected from 14 individual substrate mats within four different geographic river sections during 1997 (Appendix 4). The majority (33 eggs) was collected in the Kootenai National Wildlife Refuge section from rkm 234.8 to 237.5. One egg was collected in the upper Shorty's Island section (rkm 231.6 to 233.4). Eleven eggs were collected in the Myrtle Creek section (rkm 233.5 to 234.7). Thirty eggs were collected in the Deep Creek section (rkm 237.6 to 240.5). No eggs were collected in the middle or lower Shorty's Island sections (rkm 228.0 to 231.5) or above the Deep Creek section (>rkm 237.5).

Fifty-seven (77%) of the 74 white sturgeon eggs and the one larvae collected in 1997 were viable. Stages of egg development and date of fertilization were estimated (Paragamian et al. In Press). Development ranged from stage 12 to 28 (one h to 14 d old), with 76% of the eggs at stage 21 or earlier (Table 5). Based on ages of viable eggs and the dates of egg collection, we estimated that white sturgeon spawned during at least 10 days in 1997. Spawning was first documented on June 5 (one dead egg), but no additional eggs were collected until June 11. Thereafter, collections of eggs each day were nearly continuous through June 24 (Figure 6).

The three largest spawning events, based on our sampling, aging, and back-calculation to spawn date took place: June 10 (28 eggs), June 11 (8 eggs) and June 20 (8 eggs) (Figure 6). Flows on June 10 and 11 were increasing and the flows on June 20 were dropping. The six other spawning dates yielded from one to three eggs each. Sixty-nine percent of the eggs were less than 48 h old, 7% were 48 to 72 hours old, and 24% were greater than 72 hours old of which all were older than nine days (216 h). The four oldest eggs were estimated at 293 hours old or about 12 days. We compared the average stage for sturgeon eggs collected in 1997 and 1996 to those collected in 1994 and 1995 (Marcuson et al. 1995 and Paragamian et al. 1996) using ANOVA and found the average stage in 1997 and 1996 was significantly older (P=0.0001) than those collected in 1994 and 1995. Average stages were 19 (1997), 19 (1996), 16 (1995) and 15 (1994). Further testing with Fisher's LSD indicated eggs collected in 1997 and 1996 were significantly older than 1995 (P=0.0001) and 1994 (P=0.0208).

Experimental mats with drift nets did not collect any eggs. One of the mats was lost temporarily during high water. Drift nets collected some sand but show promise as an additional collecting device and will be deployed in 1998.

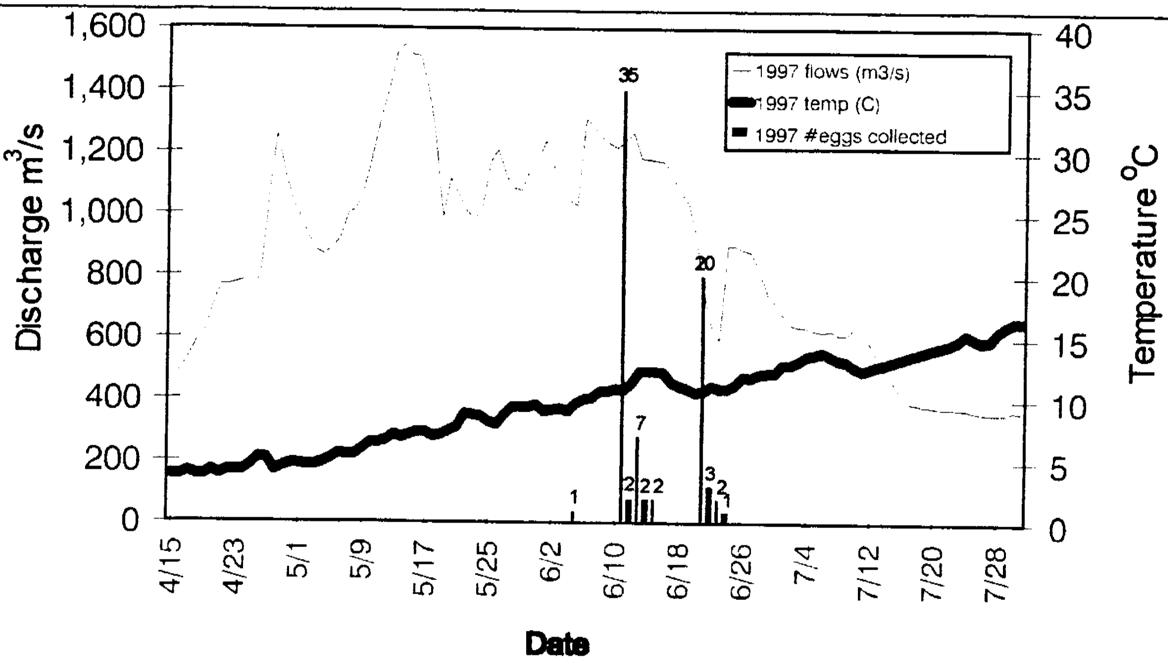
The Kolmogorov-Smirnov test was used to examine the geographic distribution of eggs during the 1994 through 1997 collections. We found significant differences in the distribution of eggs among all years (P=0.0001), eggs were progressively further upstream each year. We used the Kruskal-Wallace one-way nonparametric test to detect any statistical differences in the water velocities in the locations where eggs were collected during the four spawning years (Appendix 5). This test was not significant (P=0.776), indicating there was no detectable difference in velocities.

Juvenile White Sturgeon Sampling

We captured a total of 48 individual juvenile white sturgeon ($\leq$120 cm TL, $\leq$ 115 cm FL) with gill net and shrimp trawl effort between July 1 and August 22, 1997 (Table 1). Forty-four juveniles (92%) were hatchery fish released in 1992, 1994, and 1997 and 4 (8%) were wild fish (Table 6 and Appendix 6). Three of the 44 hatchery sturgeon were caught a second time in 1997 for a grand total of 51 hatchery and wild sturgeon. Twenty-three of the hatchery recaptures were from brood year 1995, stocked in 1997 and 14 were from brood year 1992, stocked in 1994. One of the four wild juveniles could not be aged, one was from brood year 1995, and two were from brood year 1992.

Table 5. White sturgeon egg staging data for eggs collected during the 1997 sampling season on the Kootenai River, Idaho.

Date	rkm	Depth	# Eggs	Flow .2	Flow .8	Temp (C)	Stage	Spawn Date
6-5-97	236.9	51	1	.77	.38	9.7	Dead	--
6-11-97	236.5	36	30	.36	.95	10.8	Dead	--
							13	6-11
							15	6-11
							16	6-10
							17	6-10
							21	6-9
6-11-97	238.7	37	4	.53	.70	10.8	Dead	--
6-11-97	239.0	40	1	.40	.73	10.8	Dead	--
6-12-97	239.0	43	2	.89	.99	11.4	Dead	--
6-13-97	234.0	55	5	.92	.70	12.3	Dead	--
							16	6-12
							21	6-11
6-14-97	234.0	46	2	.64	.96	12.3	Dead	--
							19	6-13
6-15-97	234.0	46	2	.92	.68	12.3	15	6-15
							21	6-13
6-13-97	237.1	46	2	1.03	.62	12.3	Dead	--
6-21-97	236.7	59	20	.54	.63	10.7	12	6-21
							15	6-21
							16	6-20
							17	6-20
							27	6-10
							28	6-12
							Larvae	6-12
6-22-97	237.0	22	3	.58	.50	11.1	Dead	--
							27	6-13
							28	6-10
6-23-97	233.4	32	1	.65	.26	10.9	28	6-11
6-23-97	234.5	47	1	.55	.43	10.9	27	6-14
6-24-97	234.3	49	1	.65	.70	10.9	27	6-15



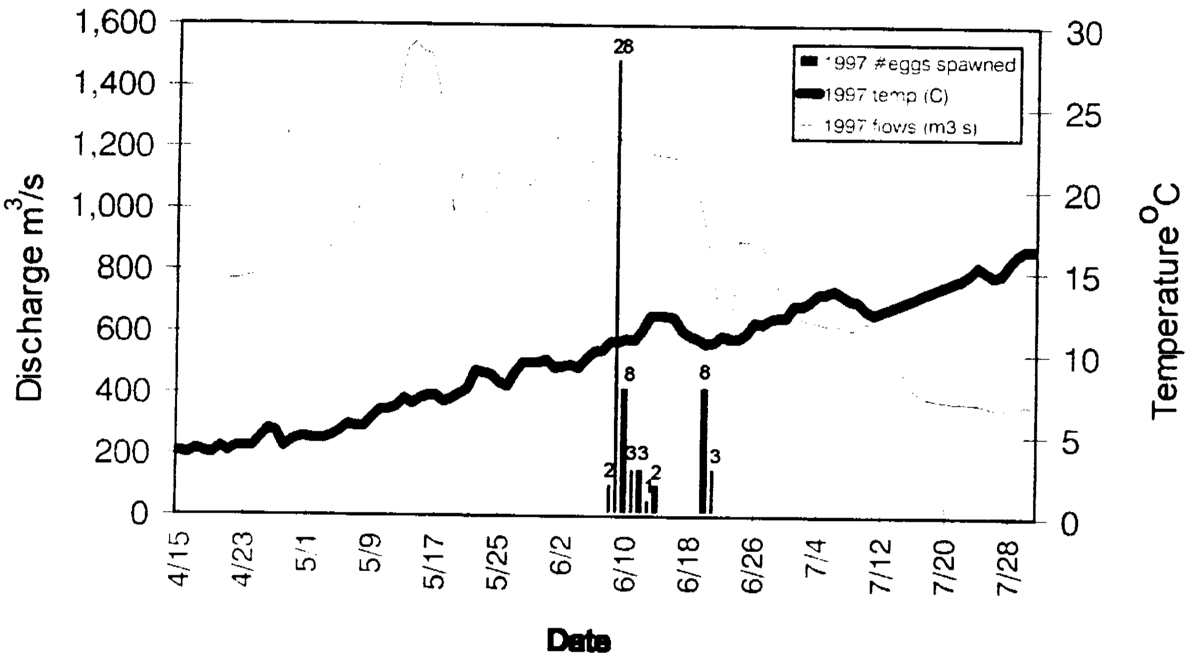


Figure 6. Top figure is collection date, number of eggs (n=75), including 1 hatched larvae, temperature (°C) and flow (m^3/s) on the Kootenai River at Bonners Ferry, Idaho during 1997. Bottom figure is spawn date, number of eggs (n=58), temperature (°C) and flow (m^3/s).

Table 6. Length, age and brood year of wild juvenile white sturgeon that fit the length definition of juvenile sturgeon captured in the Kootenai River, Idaho, January 1, 1997 to August 31, 1997.

Fish #	Date of capture #1	Length at capture #1 FL/TL (cm)	Capture rkm	Age	Brood year
3273	8/11	68/75	205	5	1992
3289	8/13	66/76	195.6	5	1992
	7/23	--/18	235.5	2	1995

Forty-seven of the juvenile white sturgeon were caught with gill nets. Gill nets were fished a total of 535 h and catch per unit effort (CPUE) was 10 h/fish. This included recaptured fish (Table 1). No juveniles were captured during adult sampling. Lengths of juveniles captured in the gill nets ranged from 21 to 97 cm FL (8.3 to 38.1 in) and weights were 0.01 to 1.9 kg (0.02 to 4.18 lbs) (Appendix 6).

Juvenile sturgeon were caught at various locations between rkm 174.3 and rkm 234.5 in water 9.1 to 27.4 m (30 to 90 ft) deep (Table 6 and Appendix 6). Wild and hatchery juveniles were captured together in the same locations. The twenty-three recaptured juveniles from the 1997 release were sacrificed for identification and enumeration of stomach contents.

A total of 39.55 hours of shrimp trawl effort was expended to sample for juvenile white sturgeon in the Kootenai River (Table 1). Tows averaged 21.78 minutes each. Only one juvenile white sturgeon was captured. On July 23, we captured an 18 cm (TL) (7.1 in) juvenile sturgeon from the 1995 year class at river kilometer 235.5 (Table 6).

Juvenile White Sturgeon Telemetry

Nine of the 19 juvenile sturgeon reared at the KTOI hatchery and released in 1994 still had active transmitters in 1997 (Marcuson et al. 1995; Paragamian et al. 1996) (Appendix 7). All fish either were released below Bonners Ferry or had moved into the river below Bonners Ferry by late October 1994. One juvenile remained in the lower river and the remaining eight stayed above rkm 170 between September 1, 1996 and August 31, 1997

Three more wild juveniles were tagged with sonic tags in August 1997. These fish were captured at rkm 205 (Ferry Island) and rkm 195.6. One of the juveniles captured at rkm 205 moved downriver to rkm 160 before returning. The other two remained in the capture locations.

Juvenile White Sturgeon Food Habits

We examined the stomach contents of twenty-three age-2 hatchery white sturgeon captured in the Kootenai River. These hatchery sturgeon were released in May 1997 and were collected for food habit analysis during July and August 1997. All stomachs examined contained food items. Food items identified included three orders of insects: Diptera, Ephemeroptera, and Tricoptera as well as oligochaetes, gastropods, and Hydracarina (Table 7). Dipterans comprised the greatest portion of the diet, numerically contributing 96% of the items (8,795 items of about 9,000 examined and identified). Chironomidae larvae comprised 92%, by number, of the insects (N=8,318) followed by Chironomidae pupae at 4% (N=395). Other items in the diet were low in comparison to the abundance of Chironomids (Table 7).

Age and Growth of White Sturgeon

Adults

Length measurements of adult white sturgeon captured between August 1, 1996 and August 31, 1997 ranged from 124 to 234 cm TL (49.6 to 93.6 in) and 108 to 207 cm FL (43.2 to 82.8 in). Growth rates of adult sturgeon captured between 1978 and 1982 averaged 3.3 cm TL (1.3 in) per year (SD=6.2) (Marcuson et al., 1995). Over the nine-year period from 1989 to 1997, 931 adult fish were caught. Fish were identified with Floy tags, PIT tags or both. Growth rates for 1997 were calculated from 196 recaptures with known fork lengths and 195 recaptures with known total lengths. Growth rates averaged 1.2 cm/yr FL (0.5 in) and 1.9 cm/yr TL (0.8 in) (SD=5.0 for FL and 5.6 for TL). Time intervals for measurements ranged from 26 to 3,417 days. The maximum measurable annual growth was 31.9 cm FL (12.8 in) and 32.7 cm TL (13.1 in).

Ages of all wild white sturgeon captured in 1997 ranged from 2 to 41 years old (Figure 7). These fish are from year classes between 1956 and 1995. Adult white sturgeon ranged in age from 18 to 41 years and were from year classes from 1956 to 1979.

Thirty-two adult fish were captured more than once during the two periods of the study (1978 through 1982 and 1989 through 1997). Thirteen were caught three times, eight were caught four times, four were caught five times, three were caught six times, three were caught seven times and one fish was captured eight times. Growth in TL for these fish averaged 2.8 cm (1.1 in) per year (SD=1.2). Intervals between multiple captures ranged from 2,610 to 5,965 days. Calculated growth (TL) ranged from 0.7 to 5.5 cm (0.3 to 2.2 in) per year. These fish should have had ample time between capture and recaptures to compensate for any influence on the fish's behavior due to stress of handling and marking.

We calculated relative weight W_r (Beamesderfer 1993) for FL and TL for 68 adult white sturgeon captured during the 1997 sampling period including a second calculation for one fish captured twice during 1997. FL W_r for adult white sturgeon ranged from 54 to 137 and the mean was 86 (SD=14.4) (TL W_r ranged from 46 to 124, mean=77, SD=13.1).

Table 7. Food items found in 23 age-2 hatchery white sturgeon captured in the Kootenai River, Idaho, 1997.

Food item	Percent of stomachs with food item	Percent of stomach contents	Number of items	Total weight (g)
Diptera		96.07	8,795	12.72
Chironomidae larvae	100	92	8,318	4.7
Chironomidae pupae	97	4	395	4.5
Certatopogonidae larvae	61	1	75	2.9
Simulidae larvae	4	.04	4	.21
Empididae larvae	4	.01	1	.21
Dipteran adult	4	.02	2	.20
Ephemeroptera		.27	24	3.12
Heptagenidae	45	.23	21	2.08
Baetidae	13	.04	3	.62
Ephemeroptera body parts	9	--	--	.42
Trichoptera		.09	9	2.28
Hydropsychidae	26	.07	7	1.23
Limnephilidae	4	.02	2	.21
Trichoptera body parts	13	--	--	.84
Oligochaeta	17	2.5	234	1.04
Other		.07	7	13.91
Gastropoda	4	.01	1	.21
Hydracarina	4	.06	6	.20
Invertebrate cases	13	--	--	.41
Unknown invertebrate parts	100	--	--	4.72
Osteichthyes parts	78	--	--	3.72
Plant parts	91	--	--	4.65

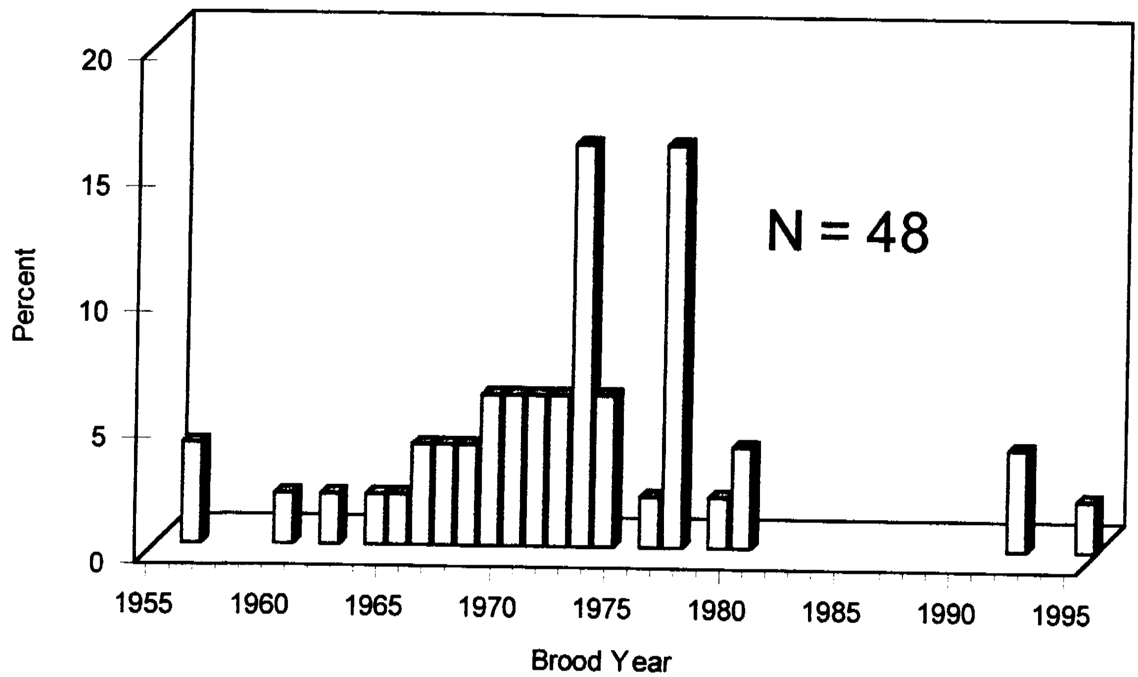


Figure 7. Ages of wild white sturgeon captured and aged in 1997, from the Kootenai River, Idaho.

Juveniles

Lengths of juvenile white sturgeon captured between August 1, 1996 and August 31, 1997 ranged from 48 to 97 cm FL (19.2 to 38.8 in) and 56 to 105 cm TL (22.4 to 44.0 in) (Table 6, Appendix 6). Ages of five wild juvenile white sturgeon (≤ 120 cm TL, ≤ 115 cm FL) ranged from two to 17 years old, placing them in year classes between 1980 and 1995 (Figure 7). Growth rates were calculated from lengths of 73 juvenile white sturgeon that were captured more than once. Average growth per year was 5.4 cm FL (2.2 in) (SD=6.6) and 7.0 cm TL (2.8 in) (SD=7.5).

We calculated W_r for FL and TL of all juvenile white sturgeon captured during the 1997 sampling period, including a second calculation for several fish captured twice during 1997. Wild juvenile white sturgeon FL W_r ranged from 82 to 87 (N=4) and the mean was 84 (TL W_r ranged from 69 to 89, mean=77). Age-2 hatchery white sturgeon (1995 year class, N=23) FL W_r ranged from 43 to 151 with a mean of 80 (SD=25) (TL ranged from 35 to 140, mean=70, and SD=24.7), age-5 hatchery white sturgeon (1992 year class, N=13) FL W_r ranged from 38 to 121, mean=88 (SD=20) (TL W_r ranged from 36 to 91, mean=75, and SD=20), and FL W_r of age-6 hatchery white sturgeon (1991 year class, N=10) ranged from 83 to 121, mean of 97 (SD=13) (TL W_r ranged from 64 to 101, mean=80, and SD=10).

Larval Sturgeon Sampling

One larval sturgeon was collected on June 21, 1997 but it was taken off an egg sampling mat rather than the net gear. No larval sturgeon were caught with the meter or half-meter net tows. We completed three hundred and thirty-eight surface and subsurface tows to sample 497,973.6 m^3 of water with meter (3.14 m^2) and half-meter (0.79 m^2) nets between Kootenay Lake (rkm 116) and Bonners Ferry (rkm 245.8). Eighty-two of these tows were at the surface and 256 were subsurface. Time of tows ranged from seven to 36.7 minutes. Sixteen tows sampling 12,224 m^3 of water were done in Kootenay Lake using the paired half-meter nets. Three hundred and twenty-two tows sampled 485,750 m^3 of water in the Kootenai River. Forty-five of the 322 tows in the Kootenai River used the meter net and the remaining 277 used the paired half-meter nets. Although no larval sturgeon were collected in larval nets other species collected include larval suckers *Catostomus sp.*, kokanee *Oncorhynchus nerka*, whitefish *Prosopium williamsoni*, and yellow perch *Perca flavescens*.

Contaminants

Nine egg samples were collected from adult female white sturgeon but they will not be analyzed until 1998.

Mitochondrial DNA Analysis

Mitochondrial DNA was isolated from tissue samples of 47 white sturgeon captured at three different locations in the Kootenai Basin; Kootenai River in Idaho, and Kootenay Lake and Duncan Lake, British Columbia. Samples were analyzed for length polymorphisms in the displacement loop (D-loop) region of the mitochondrial genome. Four distinct banding patterns were observed among samples (called A, B, C, and D) along with two additional patterns (E and F) from two individuals. Examination of the length variants indicated the river and lake samples were fairly similar. The length variant "A" was predominant in the Kootenai River sample at 55% and was higher in the lake sample at 72%. The "C" and "D" length variants were similar in both samples. The four samples from Duncan Lake could not be successfully amplified.

Acoustic Doppler Current Profiles

Acoustic Doppler Current Profiles were taken June 10 through 12, 1997, at discharges of 1,218; 1,240; and 1,266 m^3/s (43,000; 43,800; and 44,700 cfs), respectively. We calculated mean velocities and standard deviations for five depth profiles from a 4 m strata, 2.82 m (10.7 ft) through 6.82 m (22.37 ft) depth at 1 m (3.28 ft) increments for each reach (Table 8). This 4 m (16.4 ft) strata of the river water column encompassed the greatest portion of the river volume and because Reach 3 was shallower than the other reaches these five depth profiles allowed us to compare velocities at similar depths. Reach 1 (rkm 226.5-227) had the highest grand mean velocity at 0.87 m/s (2.85 ft/s) followed by Reach 2 (rkm 236-236.5) at 0.84 m/s (2.76 ft/s) while Reach 3 (245-245.5) was the slowest at 0.66 m/s (2.16 ft/s). The highest velocities in Reaches 1 and 2 were at depths of 4.82 m (15.8 ft) and greater while higher velocities in Reach 3 were closer to the surface. Reaches 1 and 2 had the most uniform velocities throughout the water column while there was a greater variation in the range of velocities in Reach 3.

Table 8. Mean and standard deviations of velocities at selected depths below the water surface, by reach, Kootenai River.

	Reach 1		Reach 2		Reach 3	
Depth (m)	**Vel (m/s)**	**Std Dev (m/s)**	**Vel (m/s)**	**Std Dev (m/s)**	**Vel (m/s)**	**Std Dev (m/s)**
2.82	0.83	0.20	0.82	0.25	0.79	0.37
3.82	0.85	0.19	0.82	0.23	0.75	0.34
4.82	0.88	0.17	0.85	0.22	0.67	0.32
5.82	0.89	0.16	0.85	0.22	0.59	0.35
6.82	0.89	0.16	0.86	0.22	0.53	0.35

DISCUSSION

The principle objective of this investigation is to identify the minimum discharge necessary to produce sufficient recruitment of a white sturgeon year class and to achieve recovery of the population. Seven years of study has resulted in a substantial number of eggs collected and the capture of wild sturgeon recruited from several flow test years. It may be a minimum of ten years before the complete significance of each flow year is fully understood, when progeny are near adult life stages. It is evident from egg collections, stages of eggs, flow conditions, and the capture of wild sturgeon that flows in the range of 1,130-1,300 m^3/s (40,000 - 45,000 cfs) may provide for sturgeon recruitment, and with minimal impacts to agriculture in the Kootenai Valley. Thus, we recommend a test flow for 1998 that is similar in volume and discharge to that of 1997 without impacting agricultural interests. The test should begin when river temperature approaches 9^{0}C (48^{0}F) and should be in increments of 57 m^3/s (2,000 cfs) per day to a minimum of 1,130 m^3/s (40,000 cfs) at Bonners Ferry. We also recommend no load following.

Flow conditions in the Kootenai River during spring 1997 were the highest for white sturgeon spawning since this study began. The Kootenai River rose above flood stage in May 1997 to over 1,526 m^3/s (54,000 cfs), the highest level on record after the completion of Libby Dam. However, white sturgeon continued spawning in the reach above Shorty's Island (rkm 227-237) where substrate is primarily sand and the current is slow (<0.75 m/s), despite discharges in excess of 1,135 m^3/s (40,000 cfs) and even higher Kootenay Lake elevations than 1996. We expected sturgeon to spawn in the vicinity of Bonners Ferry, where the habitat is comprised of clean cobbles and gravel and pockets of swifter water [> 2 m/s (6.56 ft/s)]. Although our fixed location receiver recorded two white sturgeon in the reach immediately upstream of Ambush Rock (rkm 245-246) we did not capture any sturgeon eggs in this reach. Eggs were collected in the vicinity of rkm 245 during white sturgeon spawning in 1991 and 1993 when the river was at lower flows but higher temperatures.

It is important to note that the flood conditions of 1997 were not the result of flow test waters but local inflow during May. This flood condition created a burden to residents of the Kootenai Valley, a situation the Kootenai River White Sturgeon Recovery Team has tried to avoid in the Recovery Plan.

The value of using Habitat Suitability Index (HSI) standards for Columbia River white sturgeon (Parsley and Beckman 1994) (Appendix 7) for sturgeon in the Kootenai River is questionable. White sturgeon in the Kootenai River continued spawning in habitat thought to be suboptimal by Columbia River standards. More importantly, four wild juvenile white sturgeon were captured during 1997 indicating recruitment is occurring from the flow test years, years in which eggs were found in "suboptimal habitat". Only depth of spawning conformed to HSI values, > 4 m (13 ft), while temperatures of 8.6 -14.5°C (47-58°F) [HSI=12-14° C (54 - 57°F)], mean column velocities of <1 m/s (3.28 ft/s) [HSI= 1.5 -2.3 m/s (4.9-7.5 ft/s)], and sand substrate (HSI=gravel and cobble) differed. Our findings may not be unusual. Kohlhorst (1976) collected white sturgeon eggs and larvae in the Sacramento River, California, over sand substrate and moderate current velocities. Sturgeon in the Frazer River, BC, are thought to spawn over sandy substrate (J. Hammond, Fisheries Manager, BCMOE, personal communication). Thus, the HSI of Parsley and Beckman (1994), while important to the Columbia River, may be river or population specific and therefore should be used cautiously in a broader application. We also recognize the location of white sturgeon spawning before the river was regulated may remain an unknown.

The capture of four wild juvenile white sturgeon recruited from flow test years and our capture of the first larval sturgeon during 1997 provided a measure of success for increased flows. Although we acknowledge our sample size is small, it is important to consider the fact that our sampling area of the river and lake is but a fraction of the total. It will therefore take many more years of sampling to achieve a more complete estimate of recruitment from flow test years. For comparison, the Kootenai River White Sturgeon Recovery Plan identifies the capture of 20 individuals from a single cohort as adequate recruitment.

Results of our Adaptive Ecosystem Assessment modeling is supported by the capture of four wild juvenile sturgeon recruited from flow test years. The modeling projected white sturgeon recovery could only be achieved by increasing flows during the spawning season (file records). The model predicted higher flows would ensure higher egg and larval survival. We also note that the average age of eggs in our collections have been significantly older ($P<0.01$) with higher flows. The oldest eggs in this study were collected in 1996 and 1997. Other investigators have identified the importance of high flows to sturgeon recruitment (Alekperov 1966; Khoroshko 1972; Votinov and Kas'yanov 1978; Parsley 1991; Parsley and Beckman 1994; Auer 1996; and Nilo et al. 1997) and mitigative measures for a Michigan River, to return to run-of-the-river flows to restore lake sturgeon *A. fulvescens,* resulted in better reproductive readiness of females, an increase in the number of spawners, and spawners spending less time on the spawning grounds (Auer 1996).

White sturgeon migration above the spawning reach (rkm 240) may be limited by shallow water (<8 m, 26.2 ft). As noted earlier, spawning depth is the only HSI criteria (Parsley and Beckman 1994) met by Kootenai River white sturgeon (>4 m, 13.1 ft). To further study this subject we summarized the telemetry locations of 26 female white sturgeon during the spawning seasons from 1992 -1997 (Appendix 8). Although our telemetry contacts were primarily during the day, our fixed location receivers seldom recorded any movement upstream of them during the night to shallower water. We also measured the depth of the thalweg from rkm 225 to rkm 247. When depth was superimposed on sturgeon locations, we found a rapid decrease in the abundance of spawning adults in the shallower water (Appendix 8). We used a generalized randomized block design to assess the interaction of month (May through July) and location (rkm). There was no interaction in one location over the other but sturgeon contacts were significantly ($P<0.05$) higher in the deeper reach (rkm 228 through rkm 240) than the shallower reach (rkm 240.1-rkm 248). Although white sturgeon may use shallow water for foraging (McKenzie and Hildebrand 1996 and

Brannon and Setter 1992) they are not known to use it for spawning. The reach utilized by white sturgeon for spawning is the furthest upstream portion of the meander reach of the river. It is also the last upstream reach deeper than 8 m (26.2 ft) for about 10 km (6.2 mi). Although some white sturgeon move through shallow water above rkm 240, to a reach of gravel and cobble substrate, our fixed location receivers indicate these journeys are brief (2-3 h). In every circumstance these fish have moved back downstream to deeper water and joined the main body of spawners. There are few records of sturgeon upstream of Bonners Ferry and we have never recorded a fish with a transmitter above this location. Also, ADCP indicated that, of the three reaches studied, the fastest flowing water (by average) is not in the reach at Bonner's Ferry nor a reach sturgeon spawn in, but a reach further downstream which sturgeon pass through to get to the spawning area.

Relative weights (W_r) of adult and juvenile white sturgeon were low in comparison to that of other white sturgeon populations (Beamesderfer 1993). However, W_r is an index that should be used with caution because it usually has more value as an index of well being for comparisons within a population. For example it will be useful in the future for Kootenai River white sturgeon for contrasts between years, cohorts, wild vs. hatchery fish, and for an individual fish captured several times over a period of years. It will therefore provide a more meaningful use after more cohorts of hatchery fish are released and when we have more information on sturgeon food habits and food availability.

Our identification of several 1991 year-class white sturgeon as wild fish has been the focus of disagreement for several years. Those that questioned our opinion argued that they may have been sturgeon that were part of an unauthorized release of fish of the 1991 cohort from the Kootenai Tribal Fish Hatchery. Therefore, we sought the advice of an unbiased, experienced person to age fin ray sections of these young sturgeon. Many fin rays from white sturgeon of known hatchery origin captured in the Kootenai River exhibited what appears to be a stress check followed by reduced growth to the next annulus. The check always occurred in the year the fish were known to be released. In 1995, we examined six fish captured in 1994 and 1995 that we believe were wild white sturgeon from the 1991 year-class. These fish did not exhibit what we believe is a stress check. Analysis of several fin ray sections of "wild" and "hatchery" fish by Larry Hildebrand (R.L. and L. Environmental Services Ltd.) confirmed that they were different. Fin ray sections of wild fish showed less growth, a smaller instar at age-1, and did not have a stress check. Therefore, the sturgeon in question were wild.

RECOMMENDATIONS

1. Spawning migration of white sturgeon commences at temperatures above 6°C. Decreases in flow or temperature following commencement of spawning could compromise spawning. Thus, the stable (no load following) flow and temperature must be maintained or allowed to increase to hold adults in the spawning reach. On or about April 15 (when water temperature is 7°C-8°C (43°F-46°F) maintain a minimum flow of 425 m^3/s (15,000 cfs).

2. Flows at Bonners Ferry during white sturgeon spawning and egg development should be maintained at no less than between 708 m^3/s (25,000 cfs) from Libby Dam for 42 days when water temperatures approach 8 to 10°C (46-50° F), to maximize egg survival.

3. Storage of warm water for tests, followed by brief three-day releases, has not benefited spawning white sturgeon. Temperature tests could restrain spawning, by retaining warm water in Lake Koocanusa if downstream river temperatures are reduced. Therefore, the storage of warm water in Lake Koocanusa for temperature tests should be discontinued.

4. Severe reductions in flow after white sturgeon spawn could strand invertebrates and larval fish in varial zones. Hence, a discharge of 311.5 m^3/s (11,000 cfs) for 30 additional days in July to early August should be provided to maintain sufficient habitat for rearing of larval sturgeon and maintain productivity.

5. Prepare Acoustic Subbottom Profiles of white sturgeon spawning sites and non-spawning habitat to help identify sturgeon spawning substrate characteristics. These studies will also determine the possible location of pre-Libby Dam cobbles that are now overlain with sand.

ACKNOWLEDGMENTS

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APPENDICES

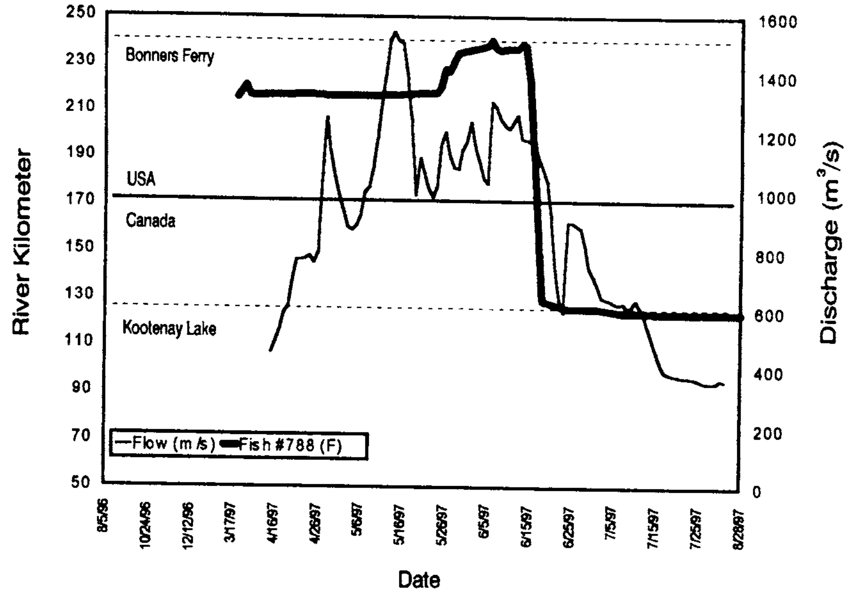
Appendix 1. Sexual development of white sturgeon sampled by IDFG, KTOI and BCMOE in the Kootenai River, Idaho, 1989 through 1997.

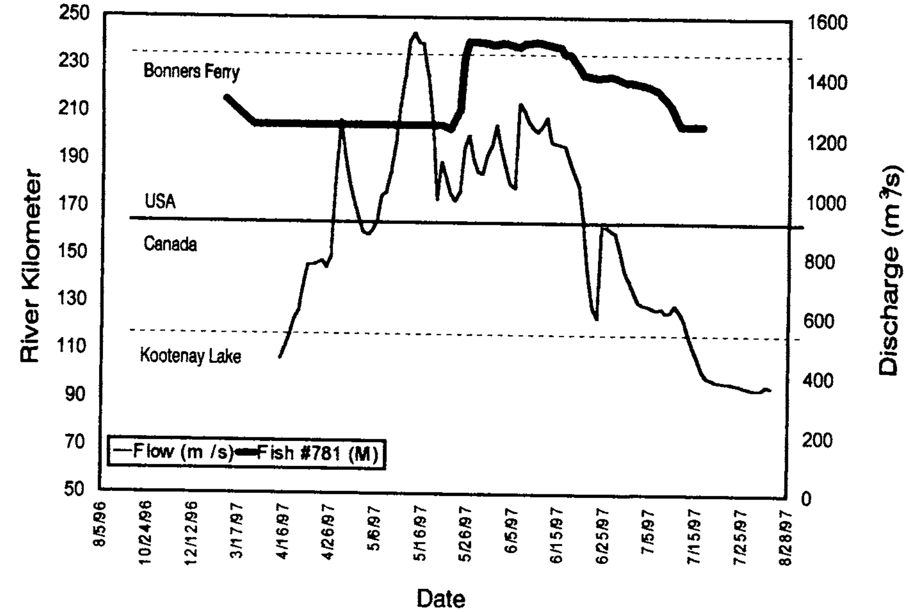
Categories of sexual development		Percent (number) of sample by year								
Category/Sex	Description of development	1989	1990	1991	1992	1993	1994	1995[a]	1996[a]	1997
0/Unknown[b]	Gonad undifferentiated or not seen	32 (58)	14 (15)	6 (3)	2 (1)	0	24 (14)	0	45 (67)	19 (14)
1/Female	Previtellogenic: No visual signs of vitellogenesis; eggs present but have average diameter <0.5 mm	14 (25)	12 (13)	8 (4)	12 (5)	0	5 (3)	11 (3)	5 (7)	14 (10)
2/Female	Early vitellogenic: Eggs are cream to gray; average diameter 0.6-2.1 mm	7 (12)	7 (8)	4 (2)	2 (1)	5 (1)	2 (1)	0	4 (6)	0
3/Female	Late vitellogenic: Eggs are pigmented and attached to ovarian tissue; average diameter 2.2-2.9 mm	6 (10)	5 (5)	8 (4)	9 (4)	53 (10)	2 (1)	0	2 (3)	1 (1)
4/Female	Ripe: Eggs are fully pigmented and detached from ovarian issue; average diameter 3.0-3.4 mm	2 (3)	5 (5)	4 (2)	9 (4)	11 (2)	14 (8)	25 (7)	5 (7)	10 (7)
5/Female	Spent: Gonads are flaccid and contain some residual fully pigmented eggs	3 (5)	1 (1)	2 (1)	0	5 (1)	0	3.5 (1)	0	0
6/Female	Previtellogenic with attritic oocytes: Eggs present but have an average diameter <0.5 mm; dark pigmented tissue present that may be reabsorbed eggs	2 (3)	0	0	0	0	0	0	1 (2)	3 (2)
R/Female	Reabsorbing eggs	0	0	0	2 (1)	0	0	0	1 (1)	0
7/Male	Non-reproductive: Testes with translucent smokey pigmentation	3 (6)	27 (30)	29 (15)	26 (11)	0	19 (11)	36 (10)	13 (20)	24 (17)
8/Male	Reproductive: Testes white with folds and lobes	32 (58)	28 (31)	18 (9)	16 (7)	21 (4)	35 (20)	21 (6)	20 (31)	29 (21)
9/Male	Ripe: Milt flowing; large white lobular testes	0	3 (3)	14 (7)	21 (9)	5 (1)	0	0	2 (3)	0
S/Male	Spent: Testes flaccid; some residue of milt	0	0	8 (4)	0	0	0	3.5 (1)	2 (3)	0

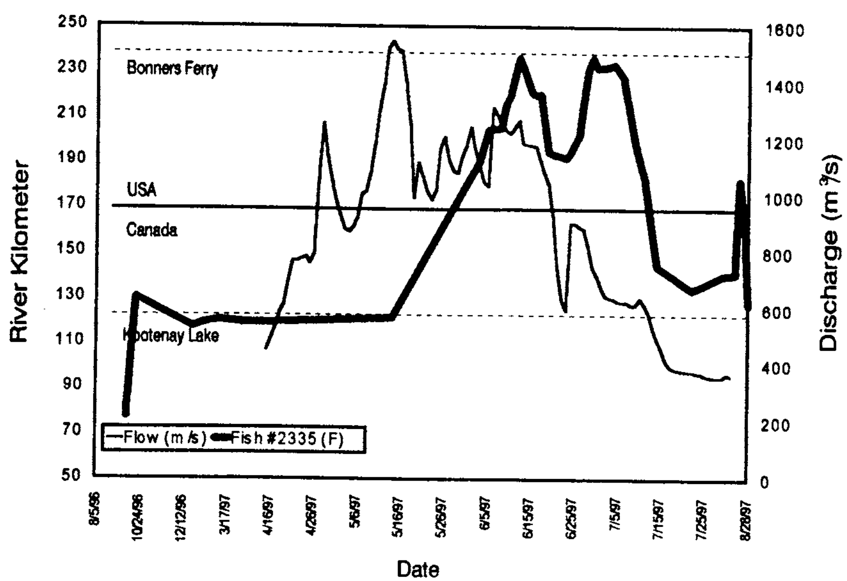
[a]Surgeries done by IDFG and KITOI were carried out on fish that externally appeared to be candidates for spawning. Surgeries done by BCME and those done during previous years were more randomly distributed among fish >130cm.

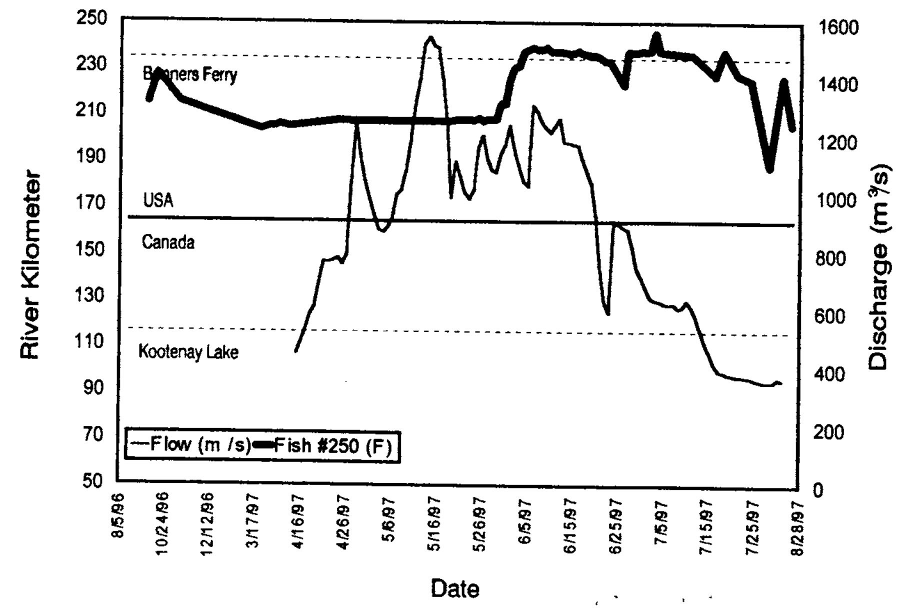
[b]Fish that we did not perform surgery on were placed in the unknown category

Appendix 2. Migration and flow (m^3s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho in 1997.

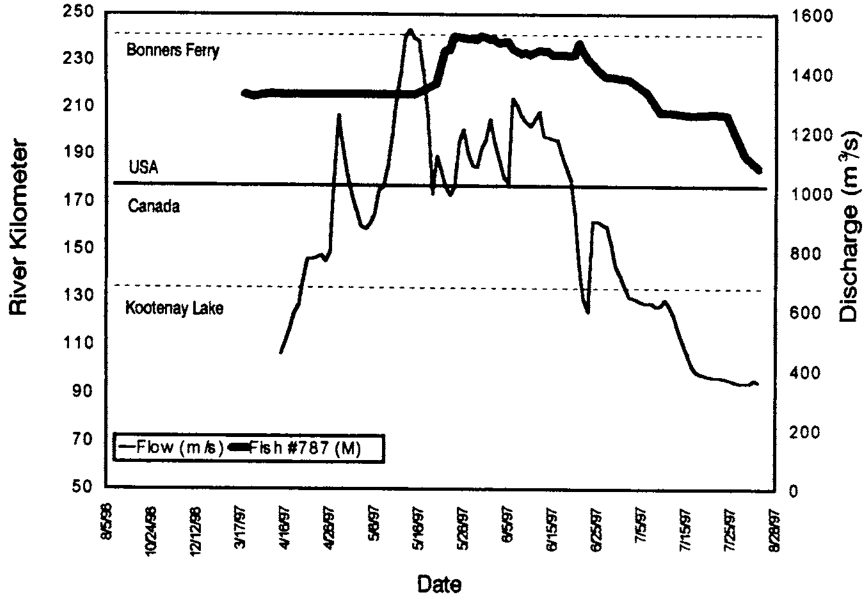


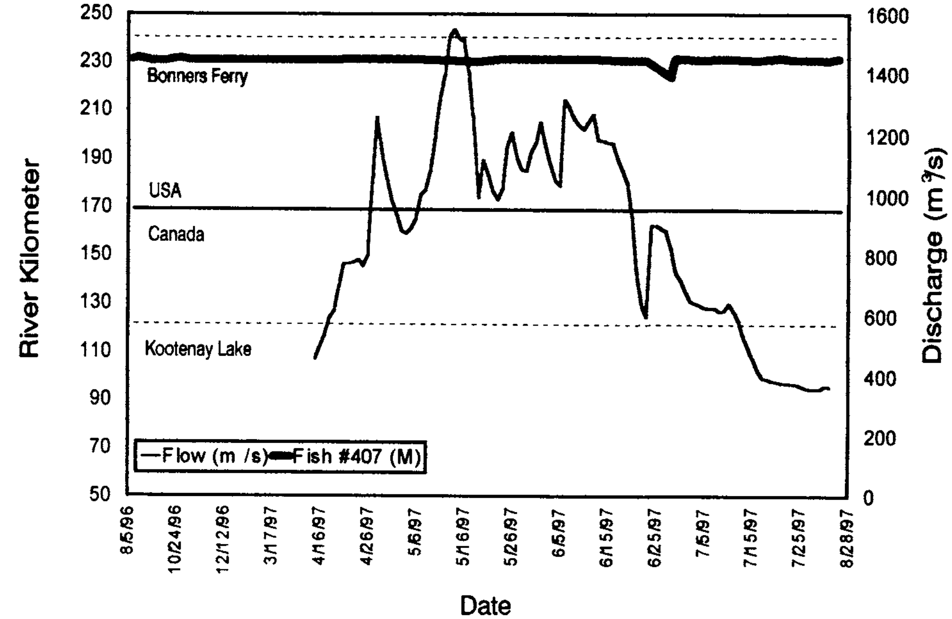


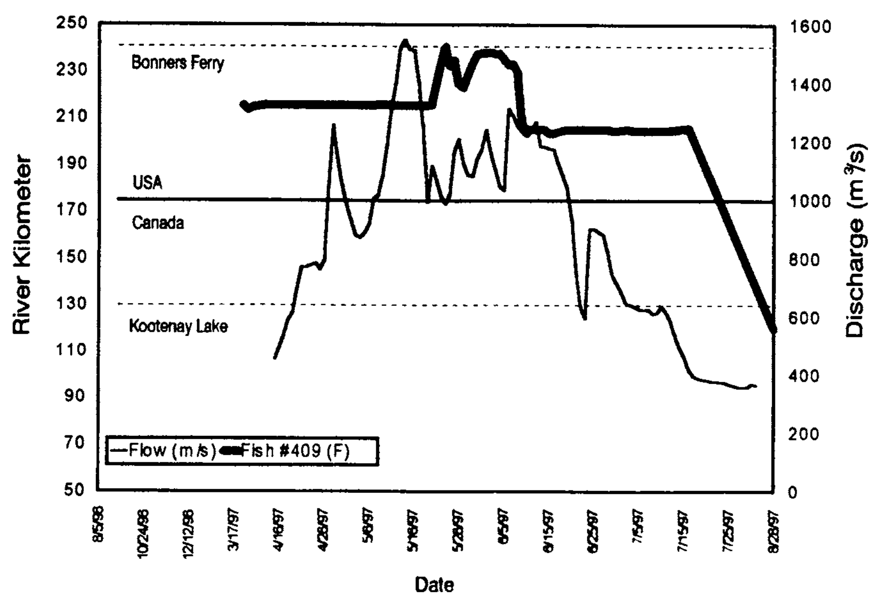


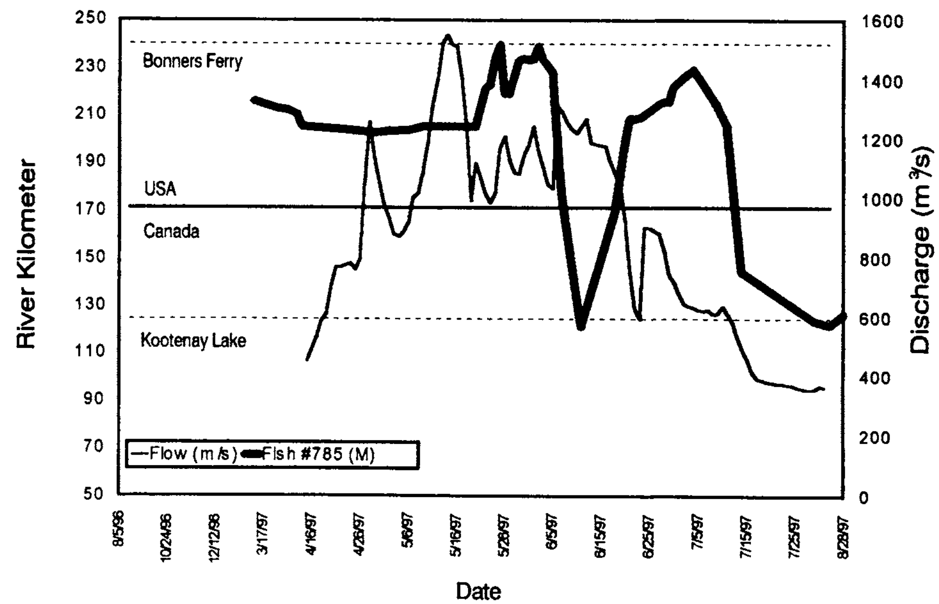


Appendix 2. Migration and flow (m^3s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho in 1997 (Continued).

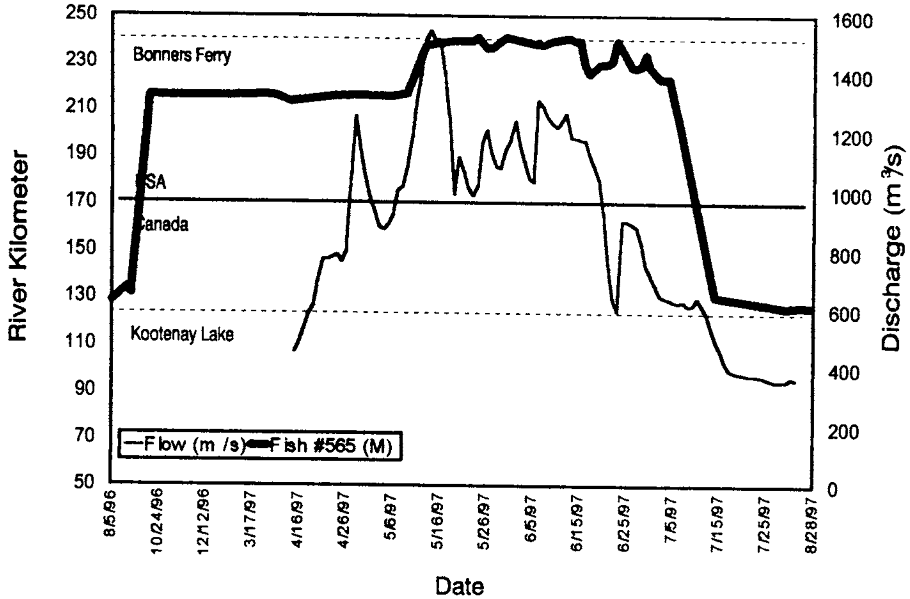


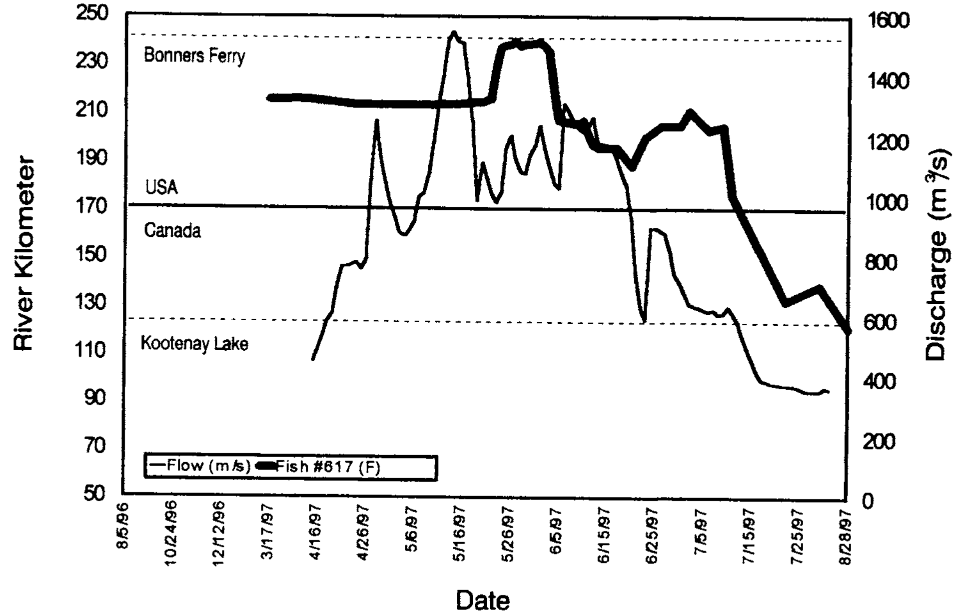


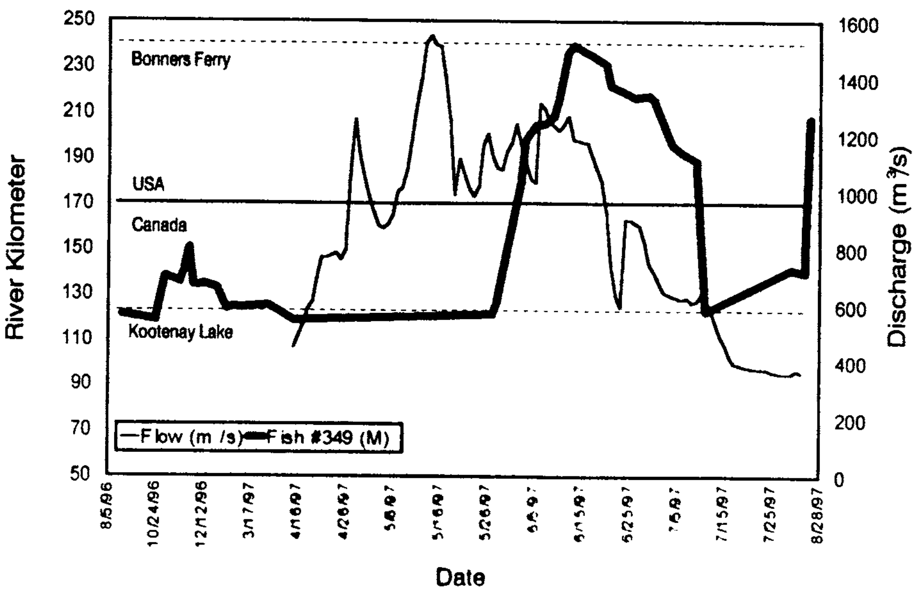


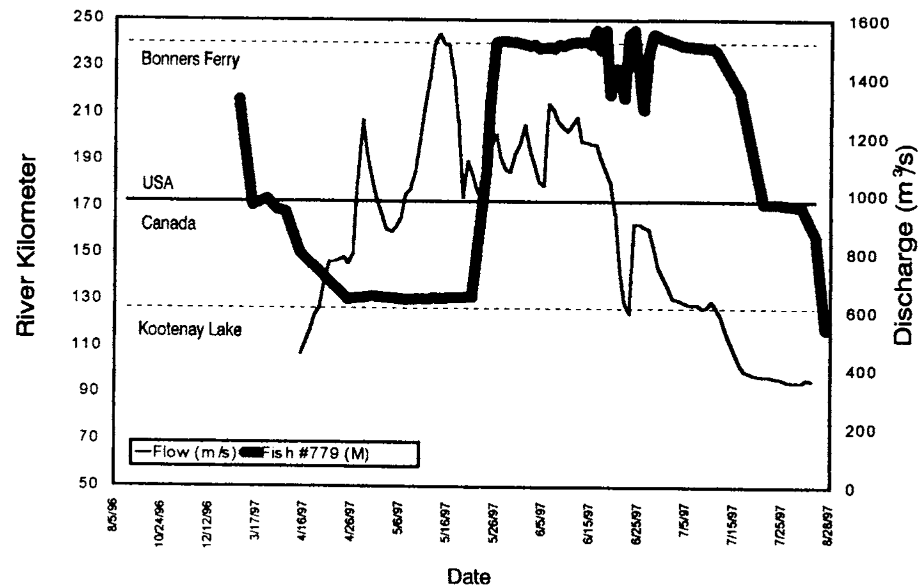


Appendix 2. Migration and flow (m^3s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho in 1997 (Continued).

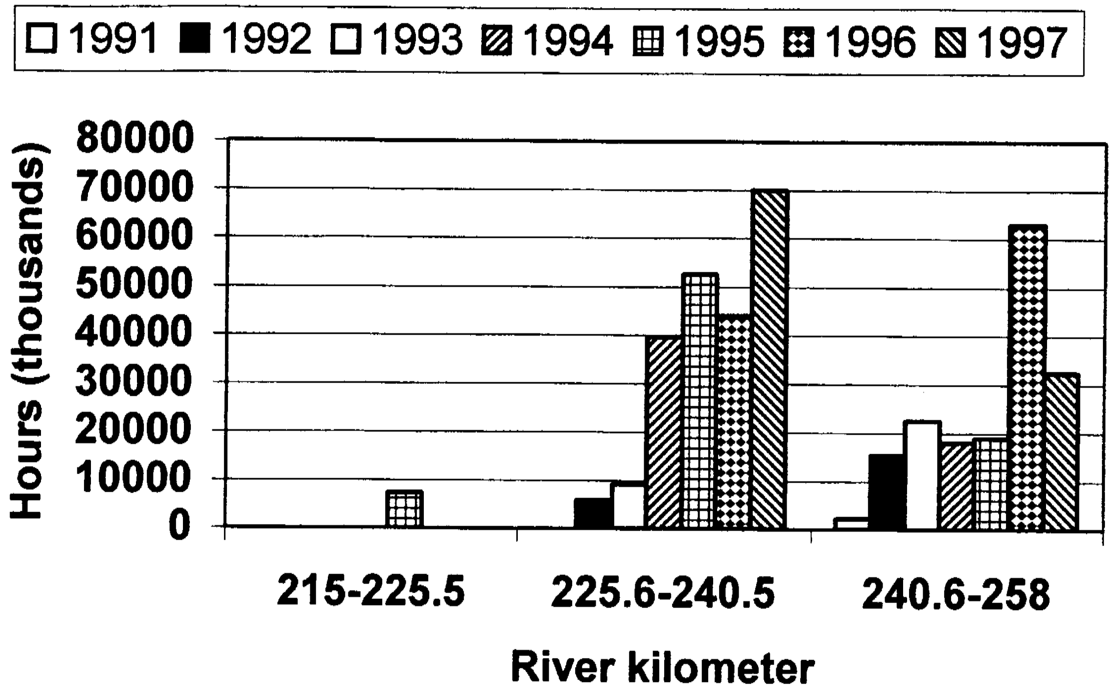








Appendix 3. Egg mat sampling effort by river section in the Kootenai River, Bonners Ferry, Idaho, 1991-1997.

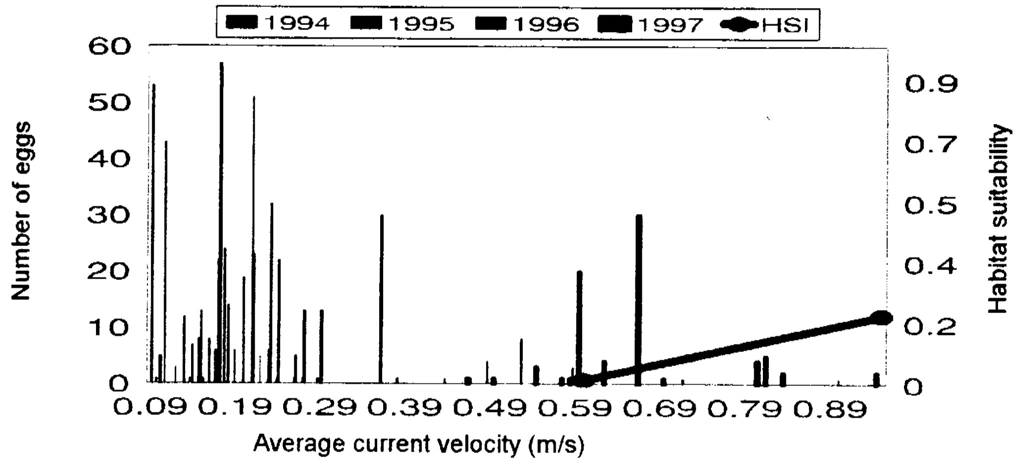


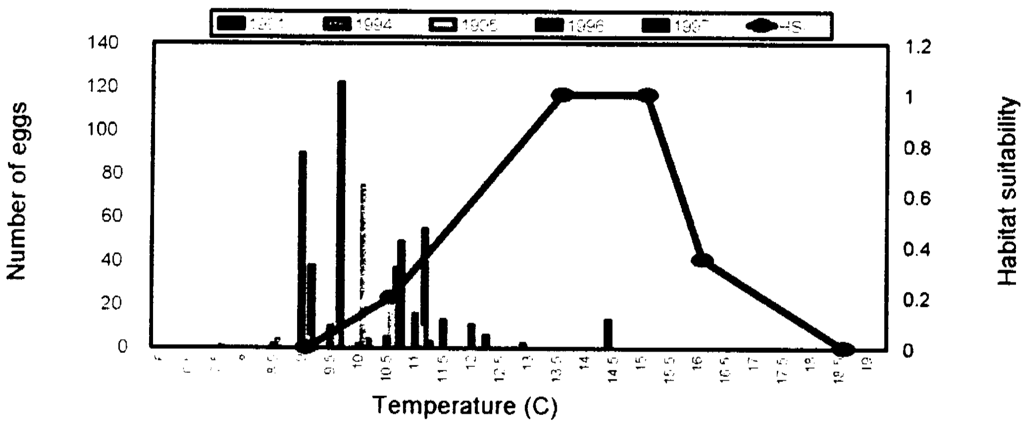
Appendix 4. River location (rkm), number of eggs, depth (m), and velocity at sites (m/s) where white sturgeon eggs were collected, Kootenai River, Idaho, 1997.

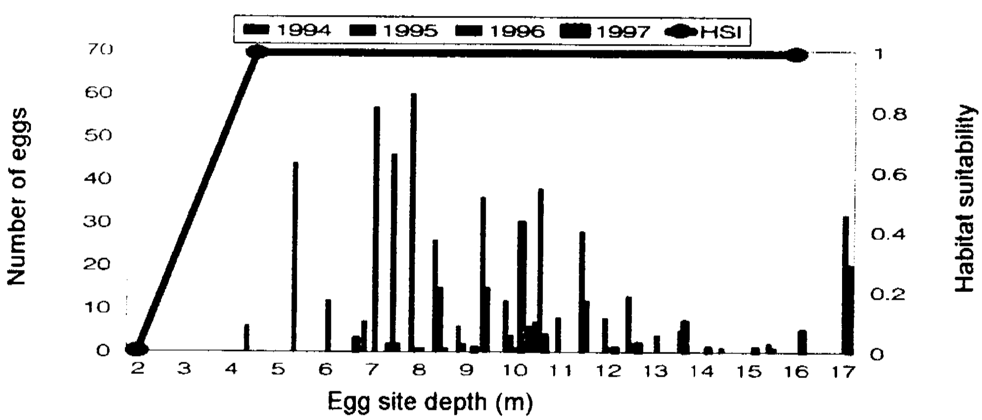
River section (rkm)	# Eggs[a]	# Mats w/eggs	Depth range (m)	Mean depth (m)	.2[b] Velocity (m/s)	.8[c] Velocity (m/s)	Mean velocity (m/s)
237.6-240.5	30	6	11.3-18	14.1	.69	.68	.68
234.8-237.5	33	2	6.7-11	8.8	.47	.73	.60
233.5-234.7	11	5	14-16.8	14.8	.74	.69	.72
231.6-233.4	1	1	9.8	9.8	.65	.26	.46
All locations	75[a]	14	6.7-18.0	13.3	.68	.66	.67

[a]one of these was a hatched out larvae
[b]2 of total depth
[c]8 of total depth

Appendix 5. Habitat suitability curves (Parsley and Beckman 1994) and habitats used by white sturgeon in the Kootenai River, Idaho, 1991-1997. Top figure is current velocity, middle figure is temperature and bottom figure is depth.







Appendix 6. Brood year, stock year, release site and recapture site for hatchery juvenile white sturgeon released into the Kootenai River, Idaho, and recaptured in gillnets between July 6, 1997 and August 31, 1997.

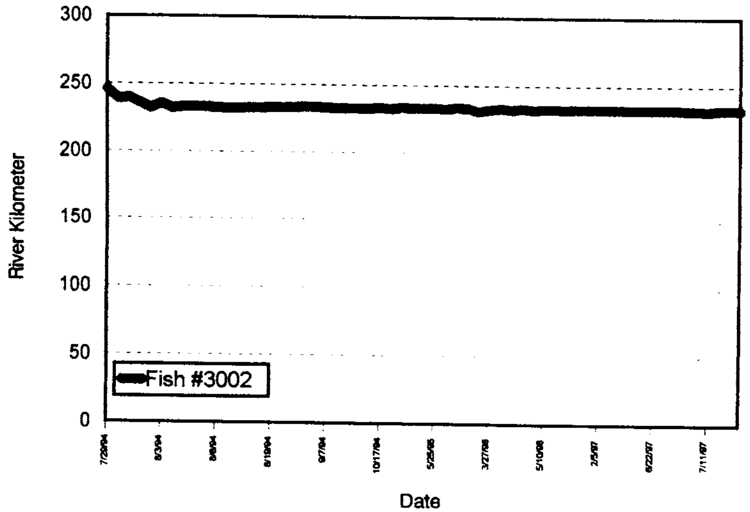
Fish #	Brood year	Stock year	Release rkm	Length at release FL/TL (cm)	Recapture date	Length at capture FL/TL (cm)	Age at capture	Capture rkm
3287	1995	1997	244.7	---	8/12	24/27	2	234.5
3291	1995	1997	244.7	---	8/18	30/35	2	225
3292	1995	1997	244.7	---	8/21	29/33	2	205
3281	1995	1997	244.7	---	8/7	25/30	2	215.2
3271	1995	1997	244.7	---	7/24	29/35	2	230.8
3262	1995	1997	244.7	---	7/14	26/31	2	225
3263	1995	1997	244.7	---	7/21	25/30	2	215.8
3280	1995	1997	244.7	---	8/5	27/32	2	225.2
3278	1995	1997	244.7	---	8/4	28/32	2	225
3285	1995	1997	244.7	---	8/12	31/35	2	234.5
3272	1995	1997	244.7	---	7/31	26/31	2	205.5
3282	1995	1997	244.7	---	8/7	27/32	2	215.7
3283	1995	1997	244.7	---	8/7	25/29	2	215.7
3250	1995	1997	244.7	---	7/14	21/24	2	225
3288	1995	1997	244.7	---	8/12	25/29	2	234.4
3284	1995	1997	244.7	---	8/12	33/38	2	234.5
3279	1995	1997	244.7	---	8/5	24/28	2	225.2
3266	1995	1997	244.7	---	7/23	25/28	2	219

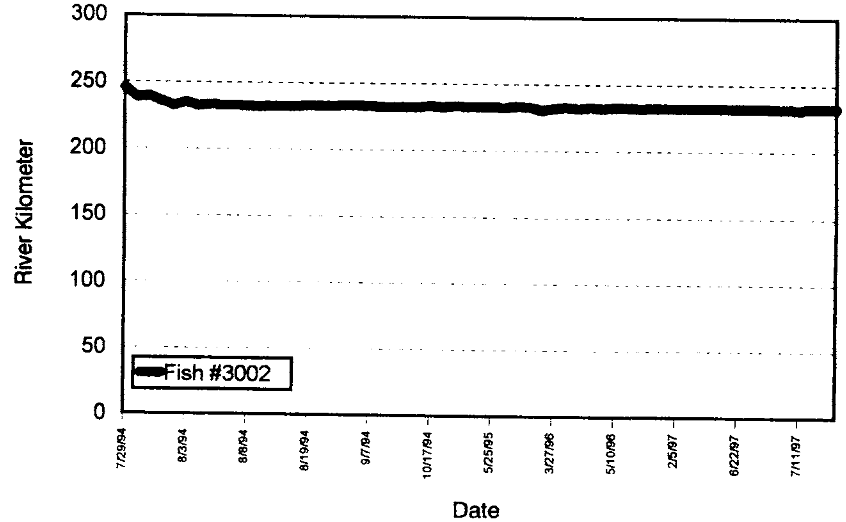
Appendix 6. Brood year, stock year, release site and recapture site for hatchery juvenile white sturgeon released into the Kootenai River, Idaho, and recaptured in gillnets between July 6, 1997 and August 31, 1997 (continued).

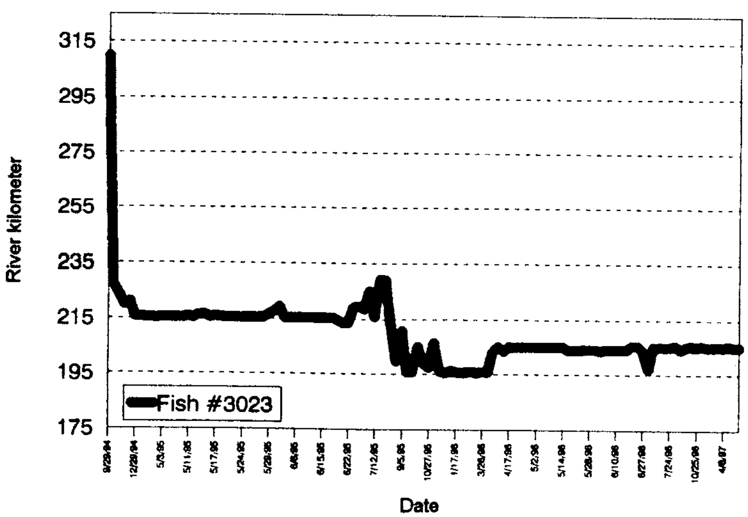
Fish #	Brood year	Stock year	Release rkm	Length at release FL/TL (cm)	Recapture date	Length at capture FL/TL (cm)	Age at capture	Capture rkm
3277	1995	1997	244.7	---	8/4	28/33	2	225
3270	1995	1997	244.7	---	7/23	22/25	2	219
3286	1995	1997	244.7	---	8/12	26/31	2	234.5
3276	1995	1997	244.7	---	8/4	28/32	2	225
3290	1995	1997	244.7	---	8/18	30/35	2	225
3049	1991	1992	243	23/27	7/15	49/60	6	215.5
3049	1991	1992	243	23/27	8/15	50/60	6	216
3050	1991	1992	243	23/26	8/7	51/61	6	215.5
3052	1991	1992	243	21/23	7/30	51/59	6	205.5
3066	1991	1992	204	22/25	7/22	56/64	6	203.4
3067	1991	1992	204	20/23	8/8	61/73	6	205
3094	1991	1992	204	20/23	8/1	63/72	6	205
3100	1991	1992	204	21/24	7/22	51/60	6	205.4
3100	1991	1992	204	21/24	8/1	55/64	6	205
3114	1991	1992	243	22/25	8/7	53/61	6	216
3138	1992	1994	244.6	32/37	8/20	60/68	5	215.7
3144	1992	1994	244.6	37/42	7/15	53/62	5	215.7

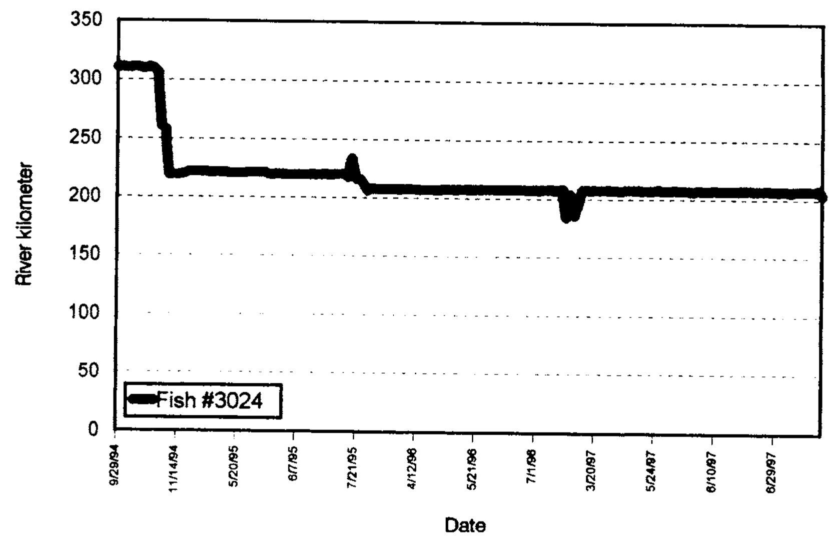
Appendix 6. Brood year, stock year, release site and recapture site for hatchery juvenile white sturgeon released into the Kootenai River, Idaho, and recaptured in gillnets between July 6, 1997 and August 31, 1997 (continued).

Fish #	Brood year	Stock year	Release rkm	Length at release FL/TL (cm)	Recapture date	Length at capture FL/TL (cm)	Age at capture	Capture rkm
3248	1992	1994	--	37/43	8/1	53/62	5	205
3185	1992	1994	--	35/41	8/1	55/65	5	205
3150	1992	1994	241.5	27/31	8/15	49/56	5	216
3151	1992	1994	241.5	31/36	8/5	49/57	5	225.1
3225	1992	1994	--	41/47	7/15	54/65	5	215.5
3006	1992	1994	203.6	60/71	8/1	65/76	5	205
3006	1992	1994	203.6	60/71	8/21	62/72	5	205
3201	1992	1994	--	38/44	8/6	56/62	5	174.3
3199	1992	1994	--	36/42	7/15	52/64	5	215.7
3164	1992	1994	244.6	37/43	8/7	57/65	5	215.8
3174	1992	1994	241.5	30/35	8/21	53/60	5	205
3026	1992	1994	310.5	60/69	7/15	57/70	5	215.6

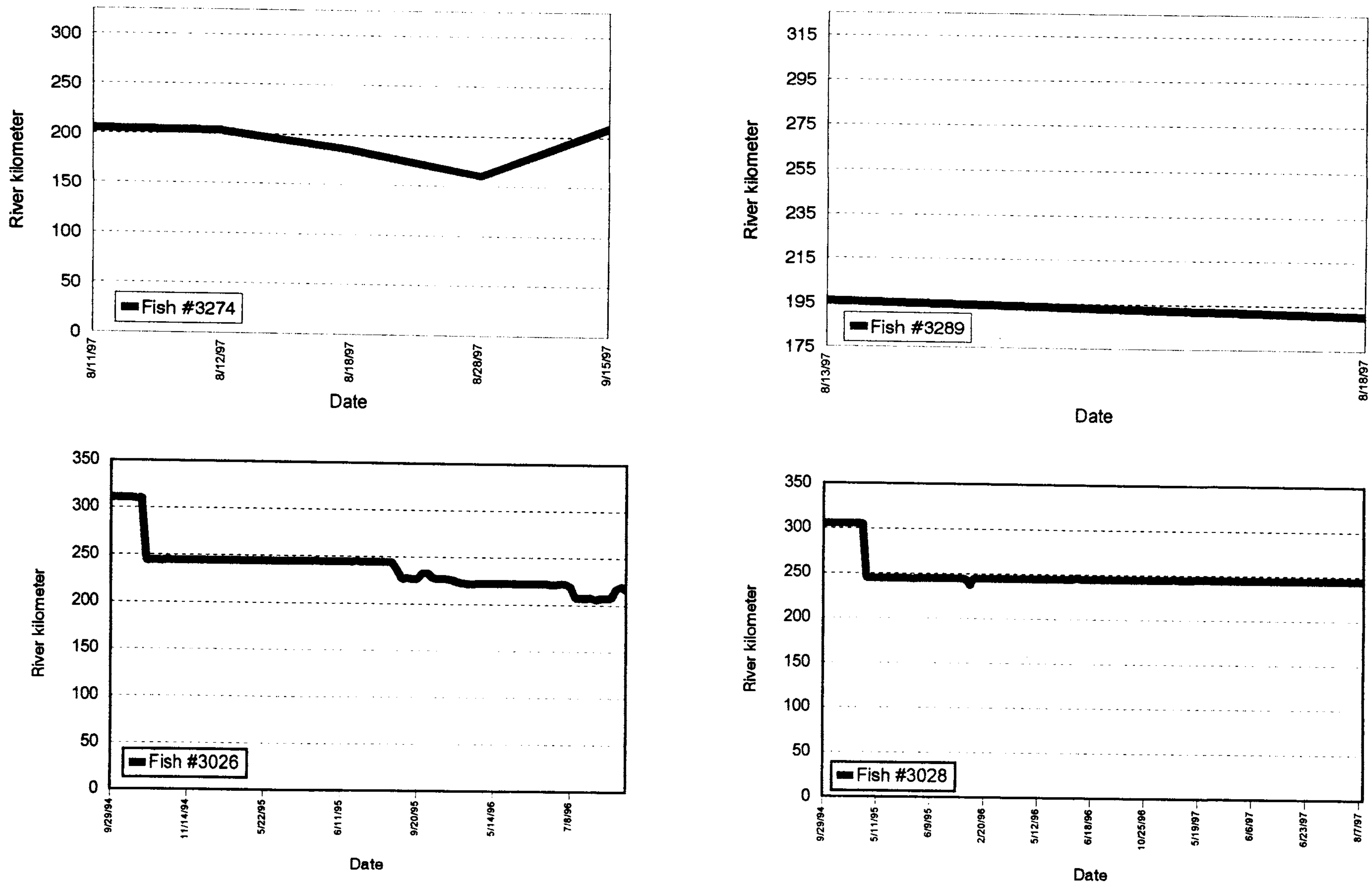




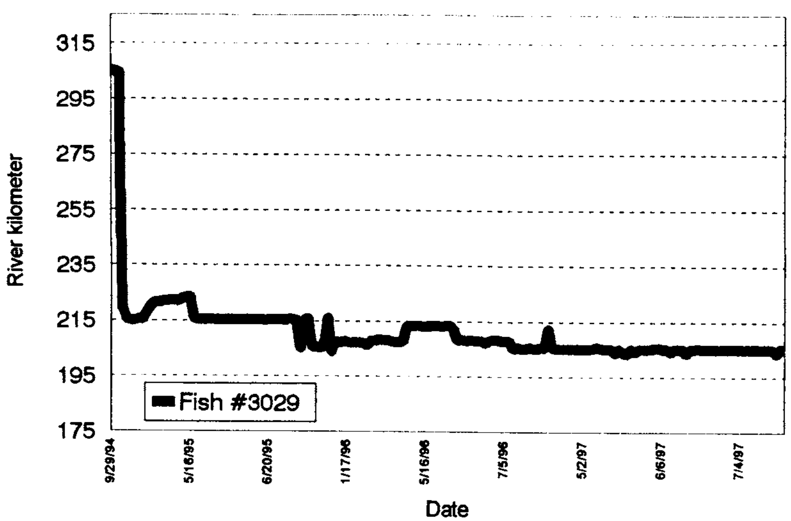


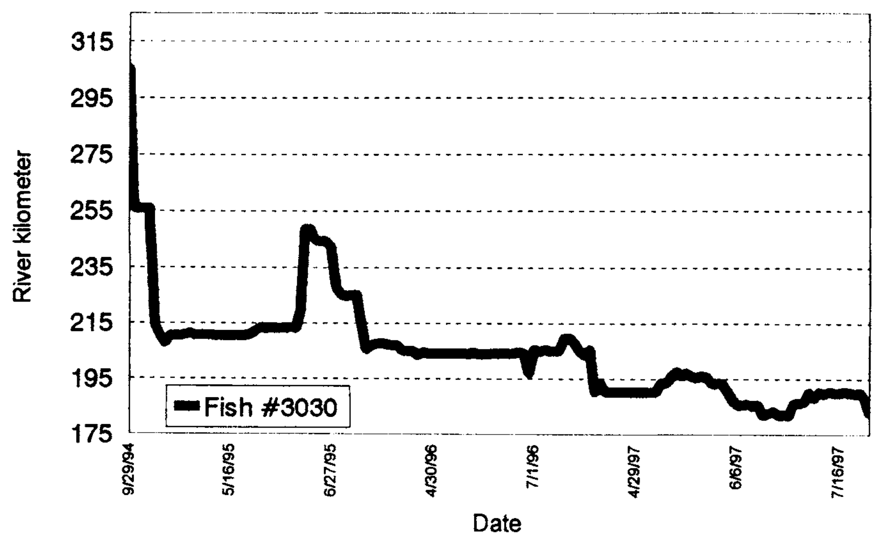


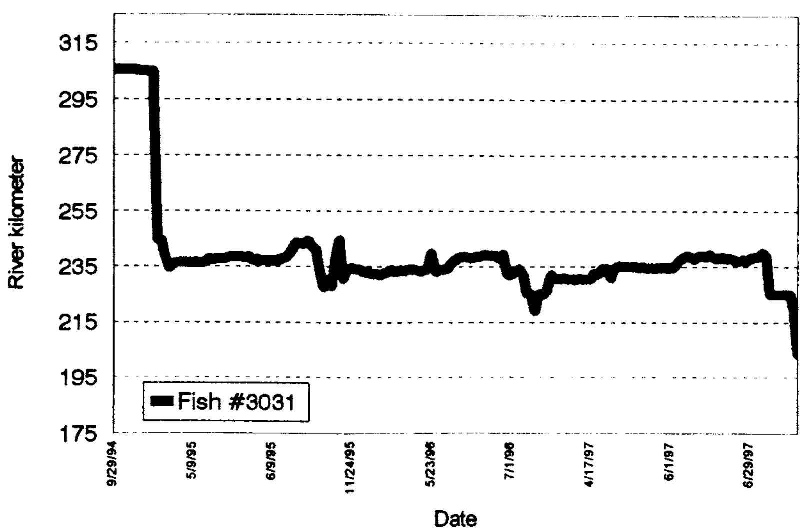
Appendix 7. Juvenile white sturgeon movement in the Kootenai River, Idaho, and Kootenay Lake, BC from 1994-1997

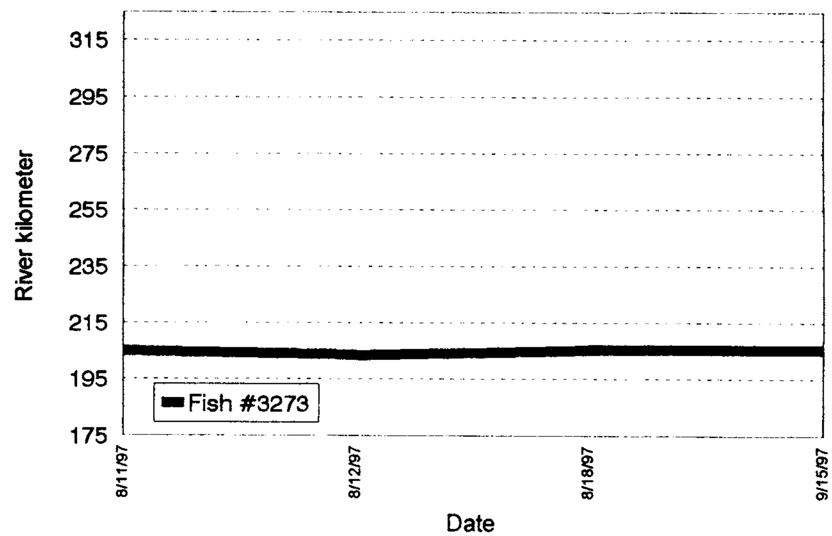


Appendix 7. Juvenile white sturgeon movement in the Kootenai River, ID and Kootenay Lake, BC from 1994 to 1997 (continued).



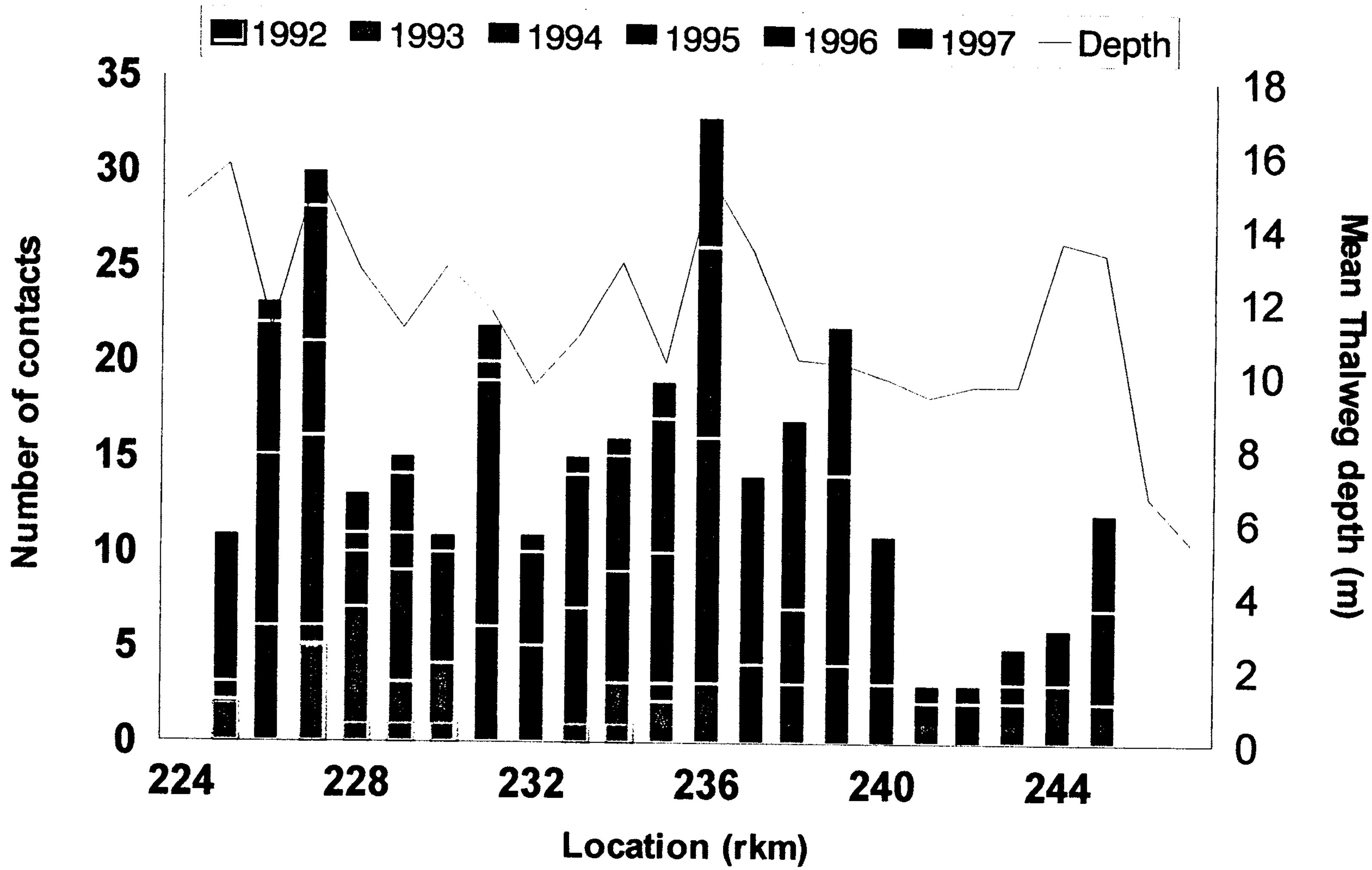






Appendix 7. Juvenile white strugeon movement in the Kooteni River, ID and Kootenay Lake, BC from 1994 to 1997 (continued).

Appendix 8. Distribution of female white sturgeon in the Kootenai River as determined by telemetry (1992 through 1997) and mean depth of the thalweg.



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